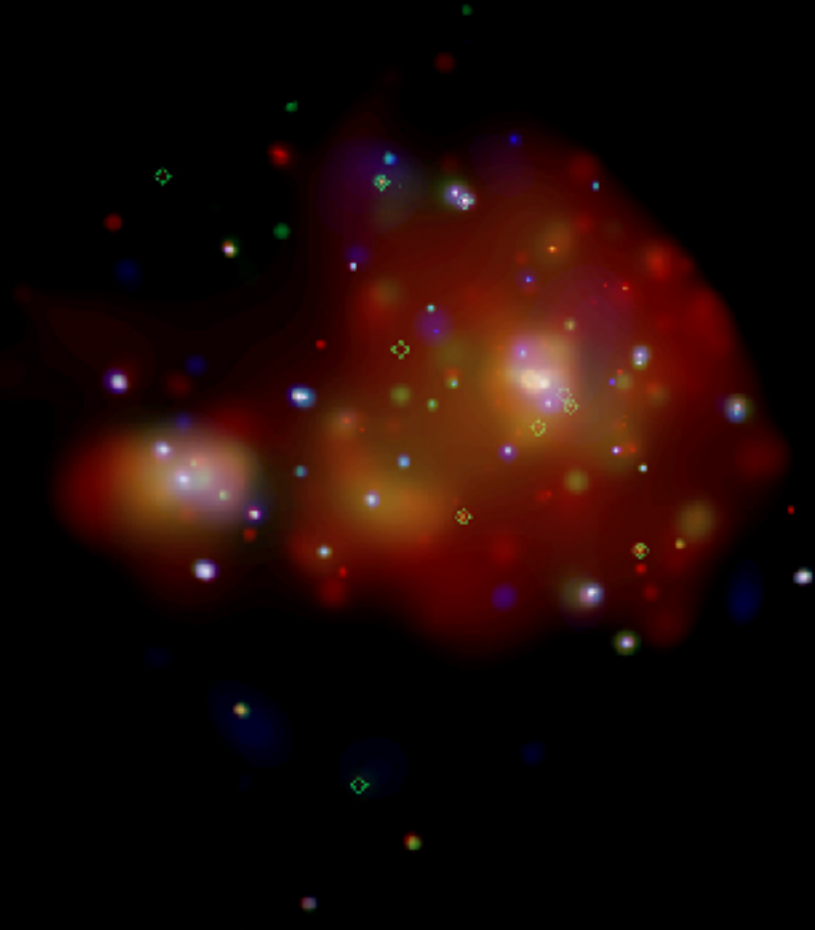
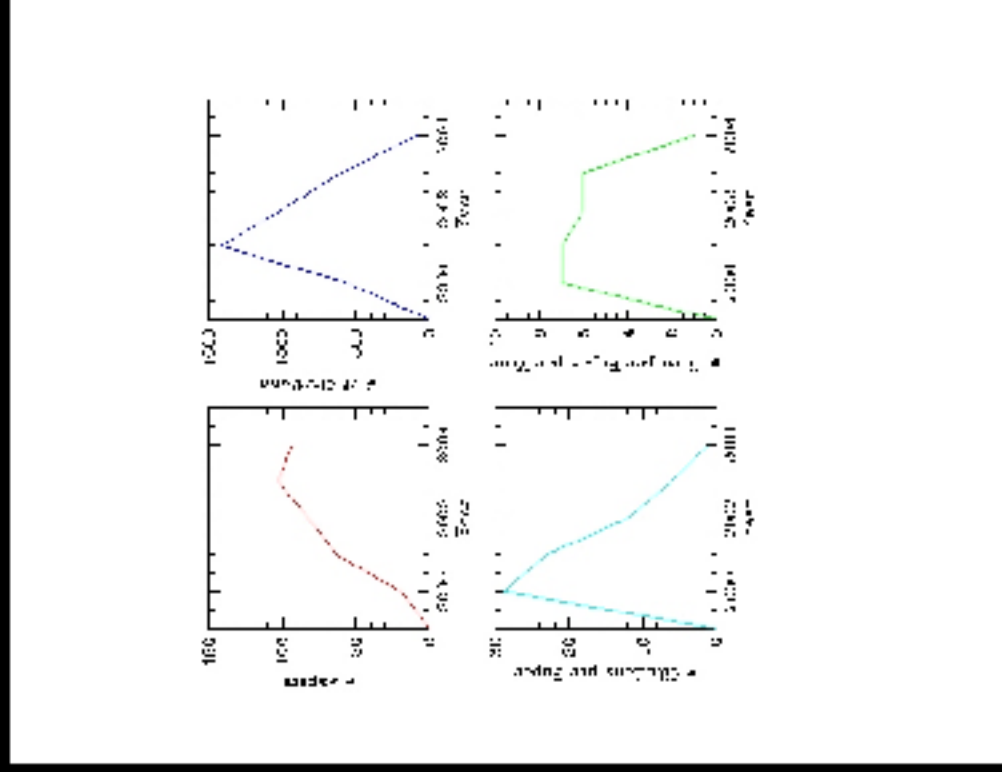


The Chandra View of X-ray Binaries



Saeqa Dil Vrtilek
Harvard-Smithsonian
Center for Astrophysics

Publication Statistics



NASA ADS 2004

- **Why X-ray Binaries?**

- **Spatial**

 - XRB Luminosity Functions

 - X-ray Scattering Halos

- **Spectral**

 - Elements and Abundances

 - X-ray line velocities

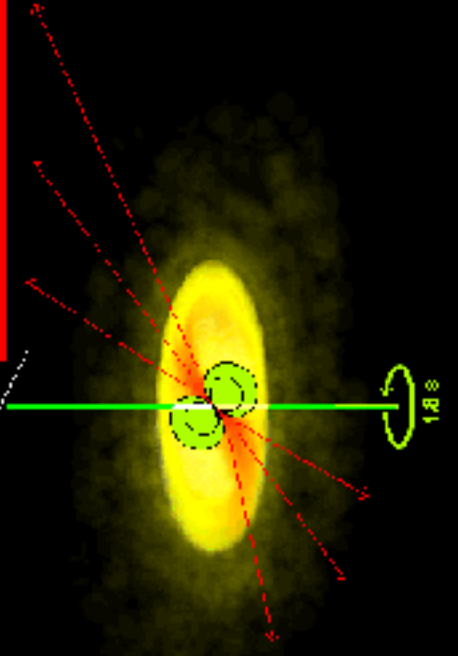
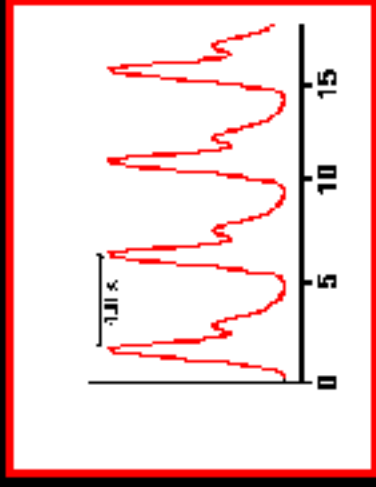
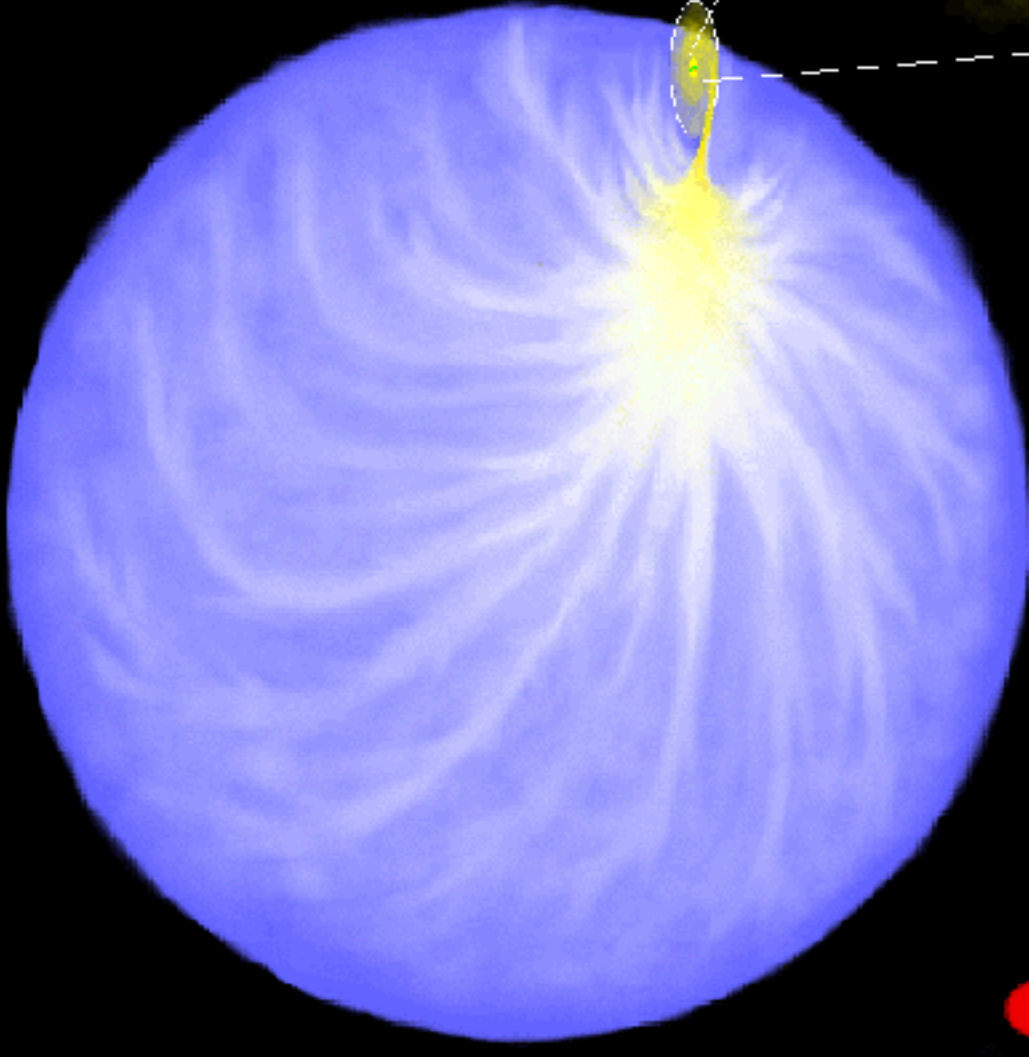
- **Future**

 - Astro-E2

 - Constellation-X

 - X-ray polarimetry

 - X-ray interferometry?



A Low Mass X-Ray Binary: 4U 1820-30



Earth

130,000 km

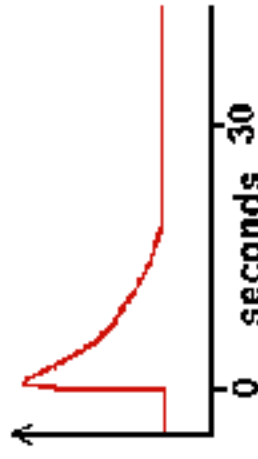
White Dwarf

Accretion Disk
Neutron Star

X - Rays

1,200 km/sec

X-Ray Emission: BURSTS



SUN

Why are X-ray Binaries interesting?

- Most efficient energy release mechanism known
- Behavior of matter under extreme conditions
- Endpoints of stellar evolution
- Most nearby, easily studied example of accretion process

What remains to be understood?

- The mass-transfer process: fundamental driver behind the most energetic phenomena in the Universe
- Angular momentum transfer/disk structure
- Equation of state of neutron stars
- Formation process of compact objects
- Origin and evolution of binary systems

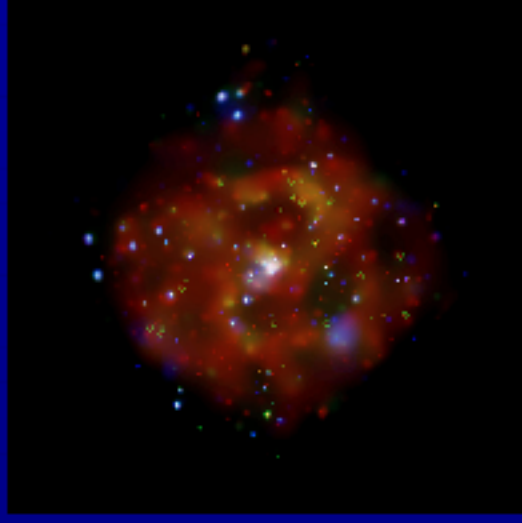
The Chandra View

Spatial

XRB Luminosity Functions

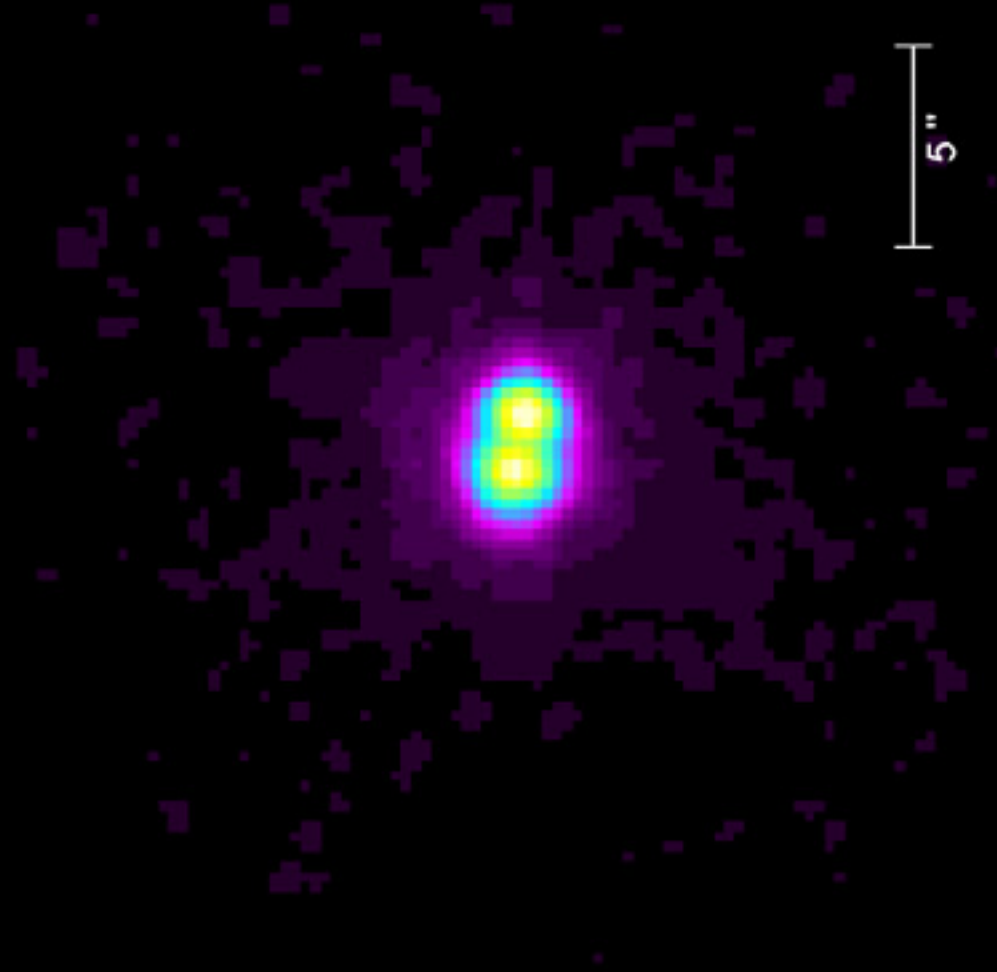
X-ray Scattering Halos

Source Identification



Double XRB in M15

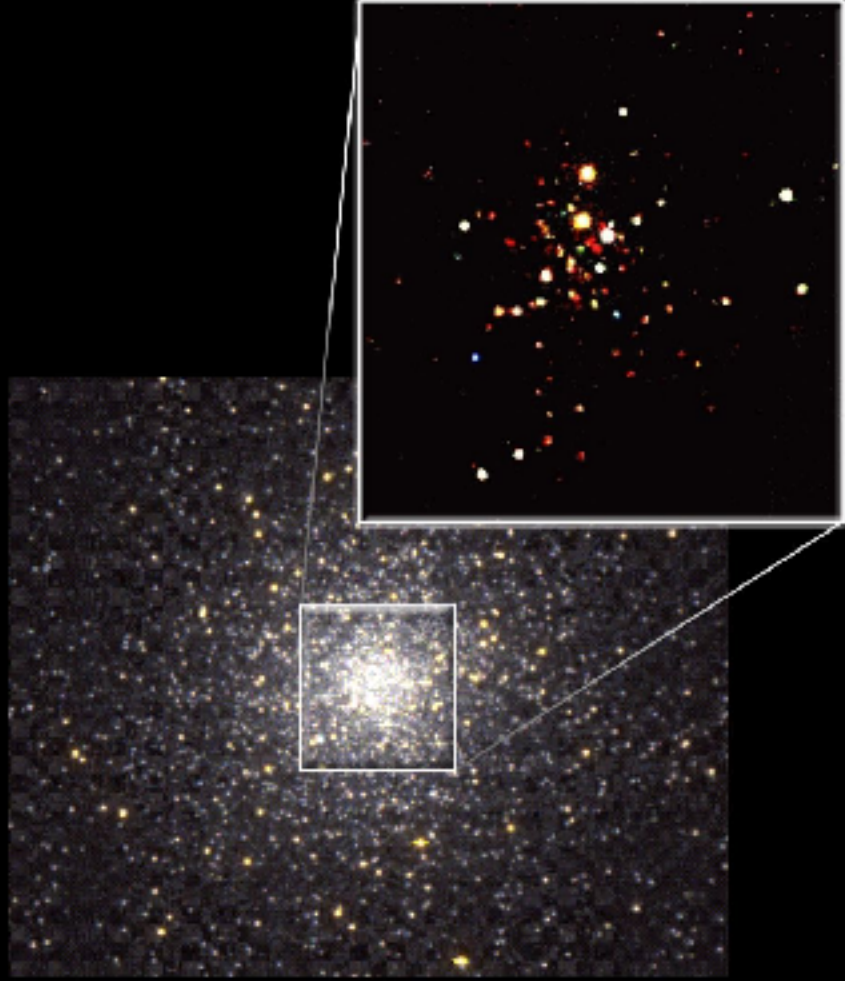
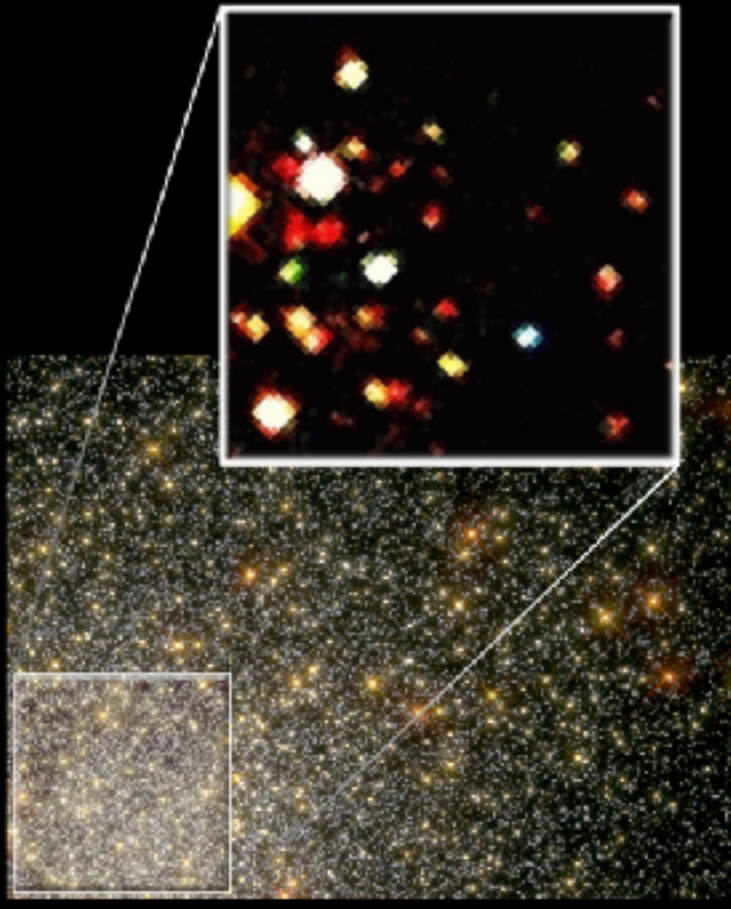
4U2127 & M15 X-2



ACIS/HETG

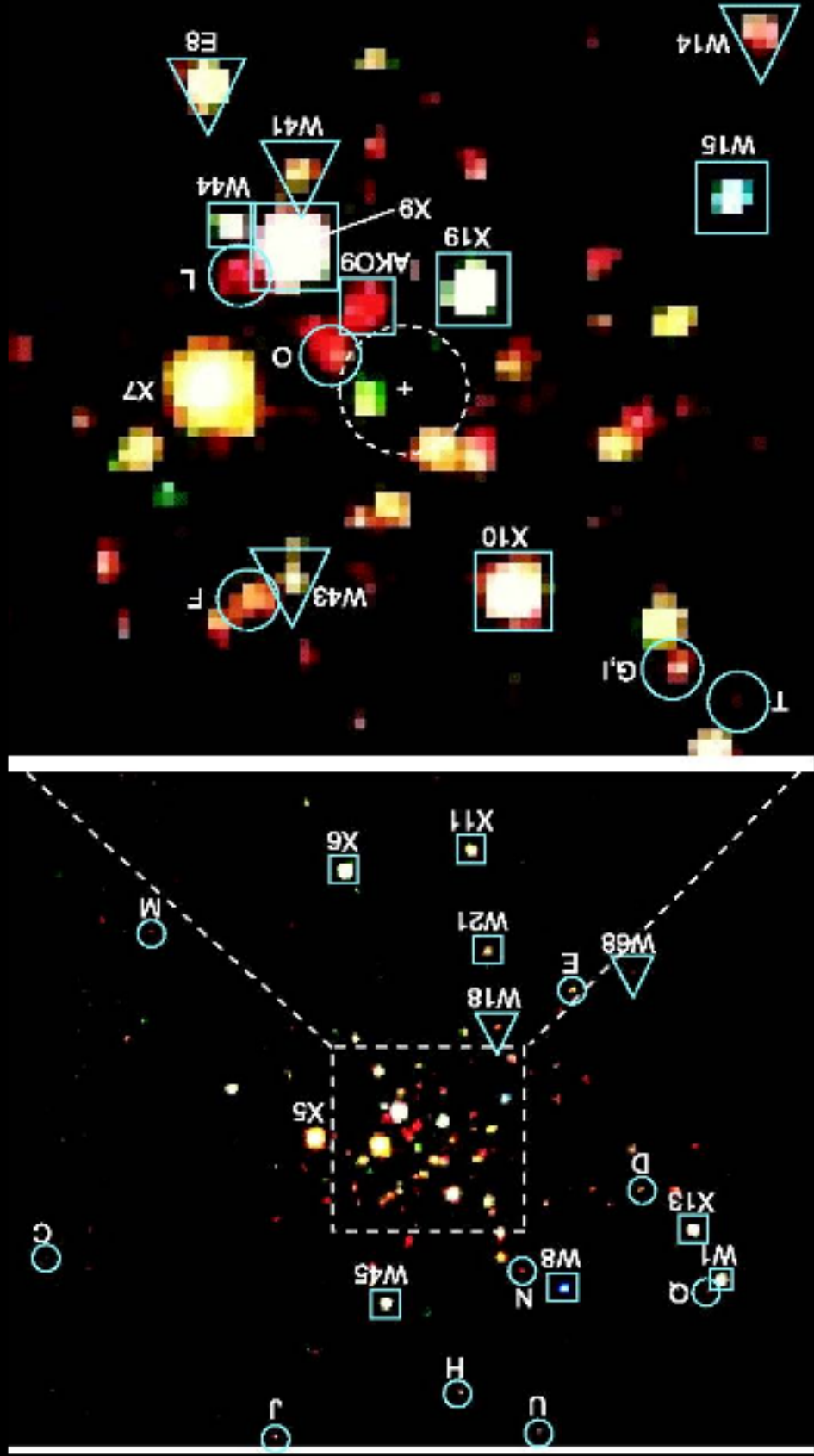
White & Angelini 2001

Globular Cluster: 47 Tuc



Grindlay et al 2001

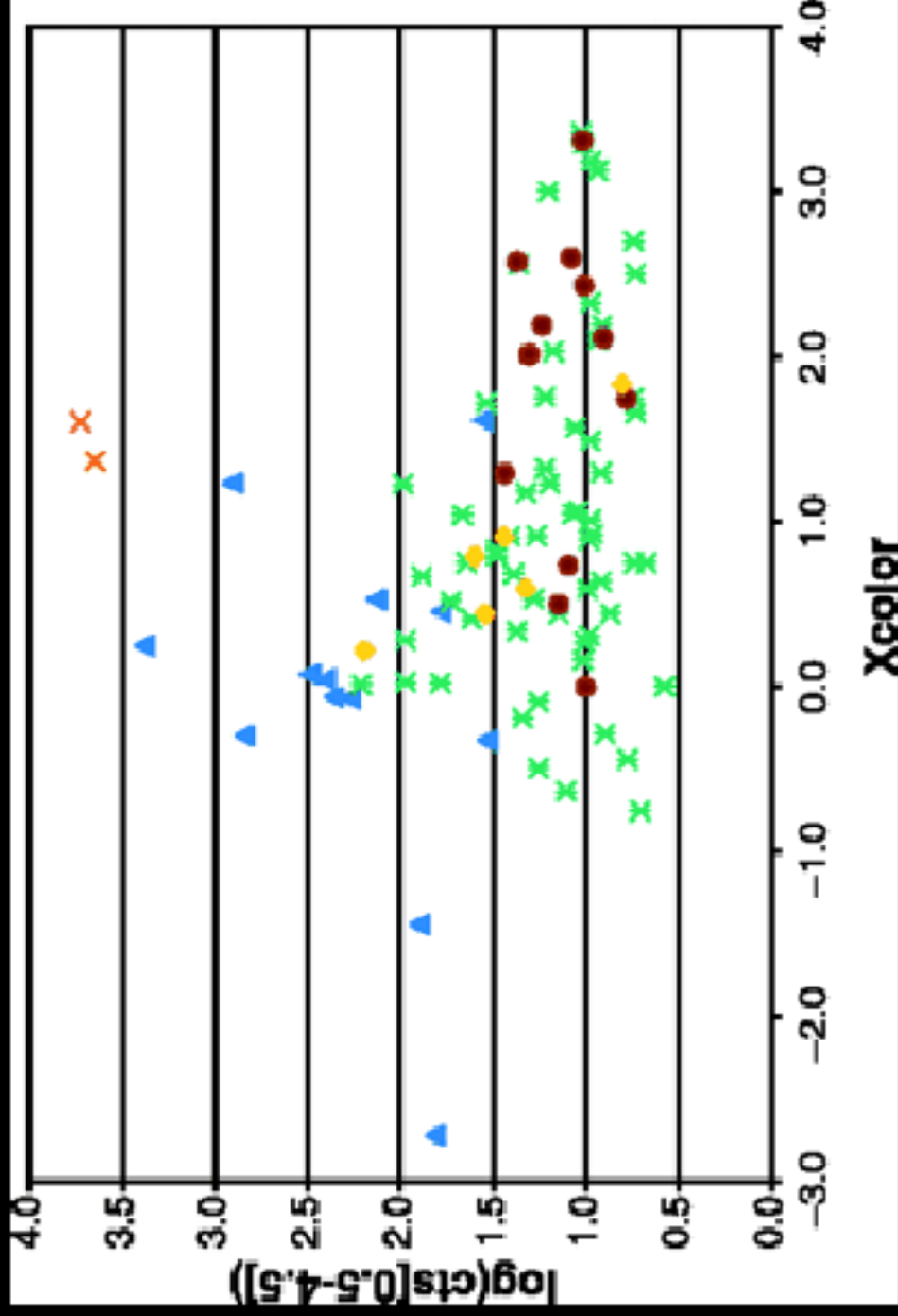
Globular Cluster: 47 Tuc



ACIS-I

Grindlay et al 2001

47 Tuc: X-ray color-magnitude



Grindlay et al 2001

XRBs in Globular Clusters



NGC 6256

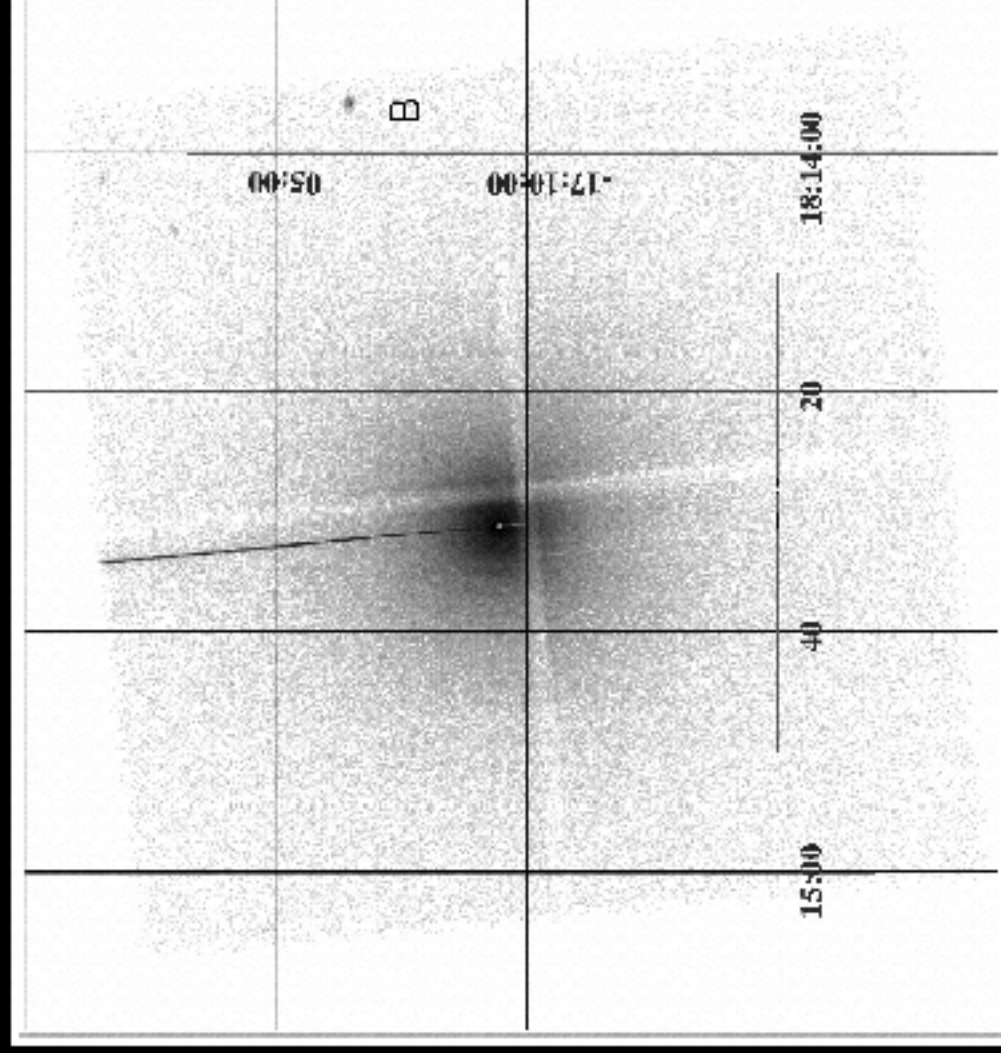


NGC 7099

Pooley et al 2003; Heinke et al 2003

X-ray Halo: GX13+1

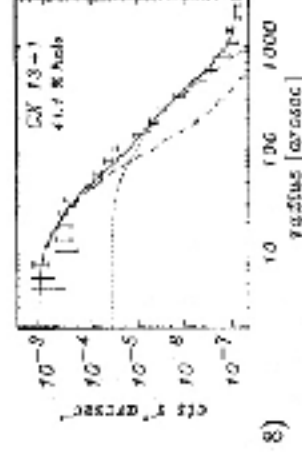
ACIS-I



Smith et al 2002

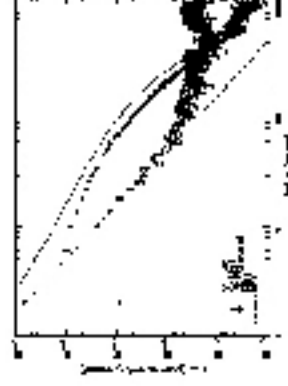
X-ray Halos: GX13+1

ROSAT



ROSAT All-sky survey observation of GX 13.1+1 (from
Friedell & Reuwill 1995)

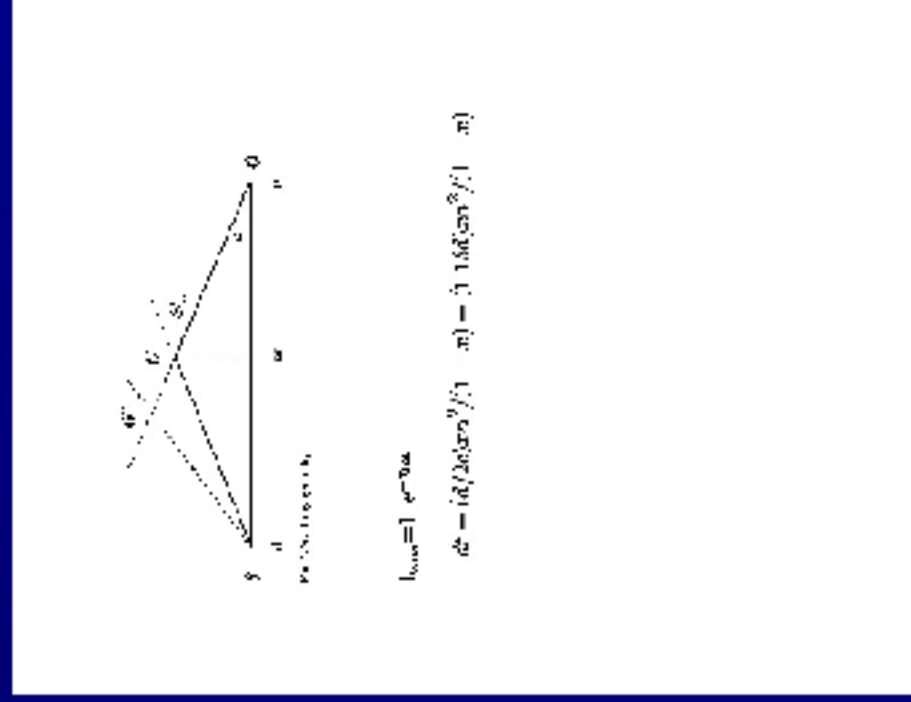
ACIS-I



Chandra ACIS-I observation of GX 13.1+1 at 2.0 keV, with
20273 shown as a point source and a simple halo model
(courtesy [Randall Smith](#)).

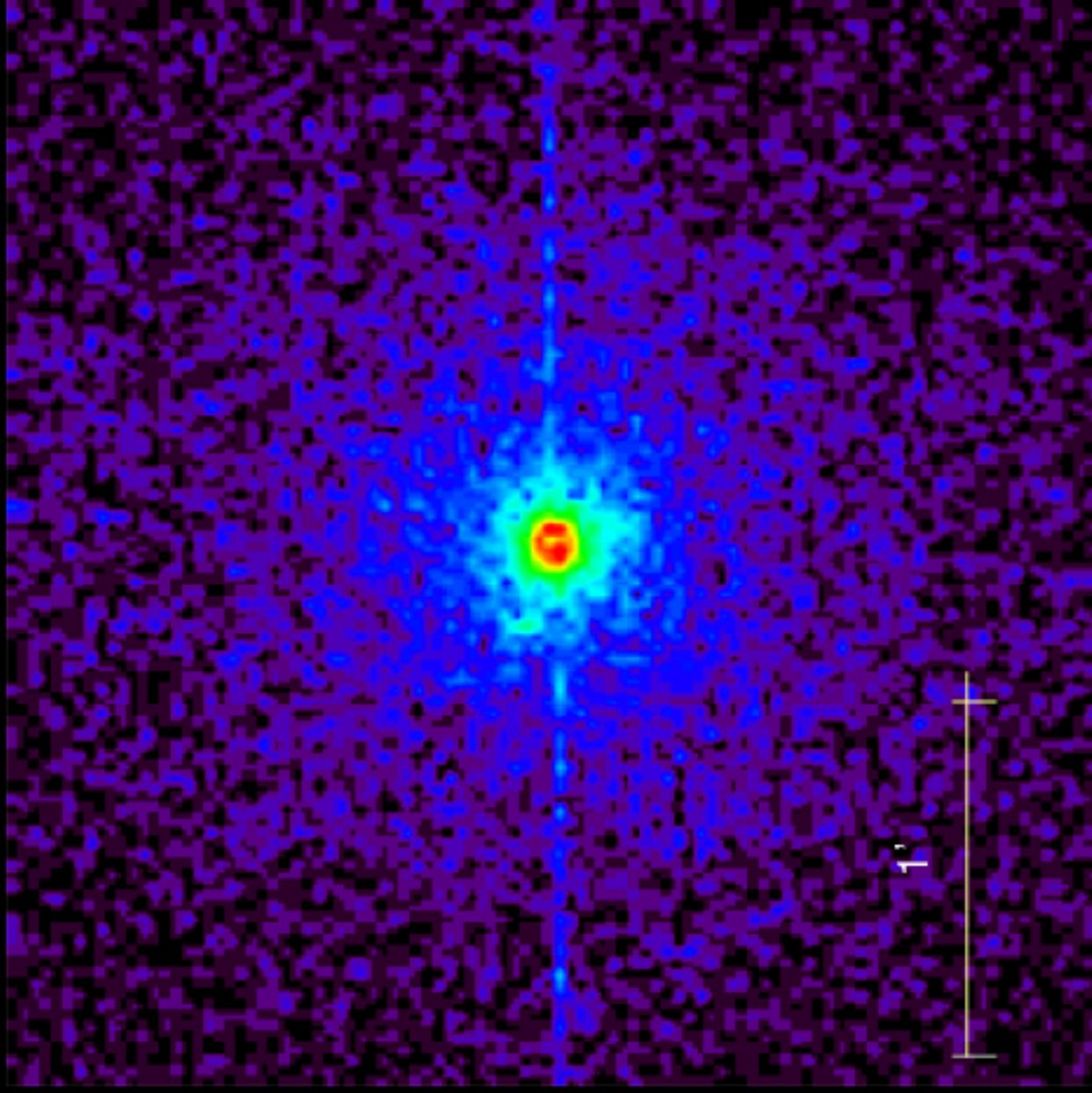
Smith 2000

Halo Scattering Geometry



Predehl et al 2000

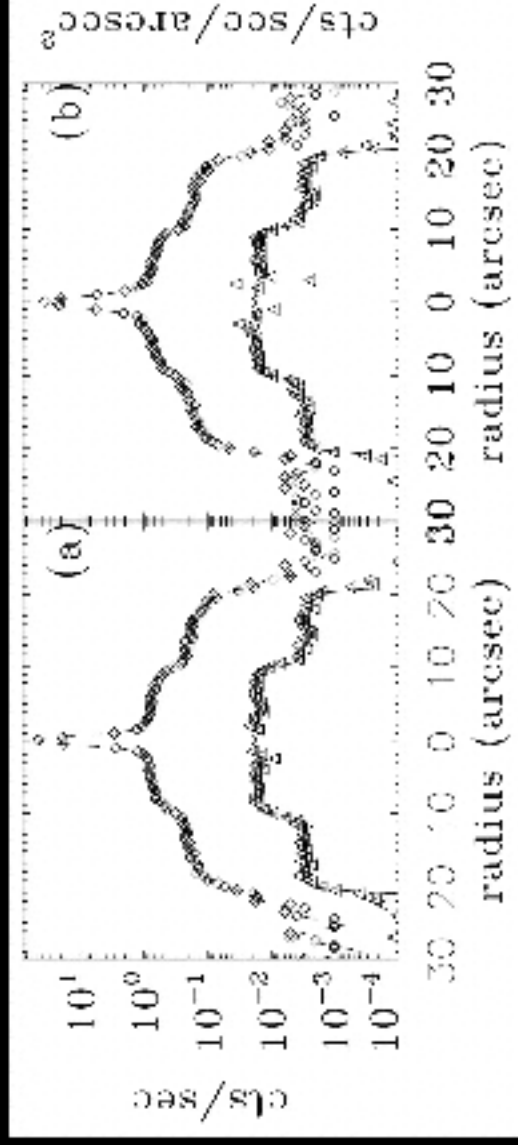
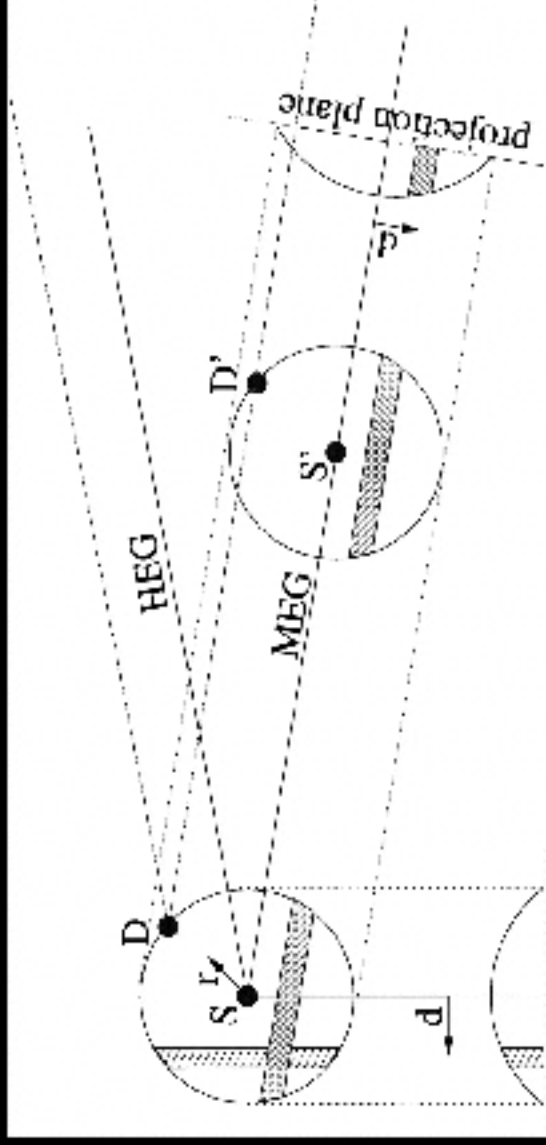
Cygnus X-3 Halo



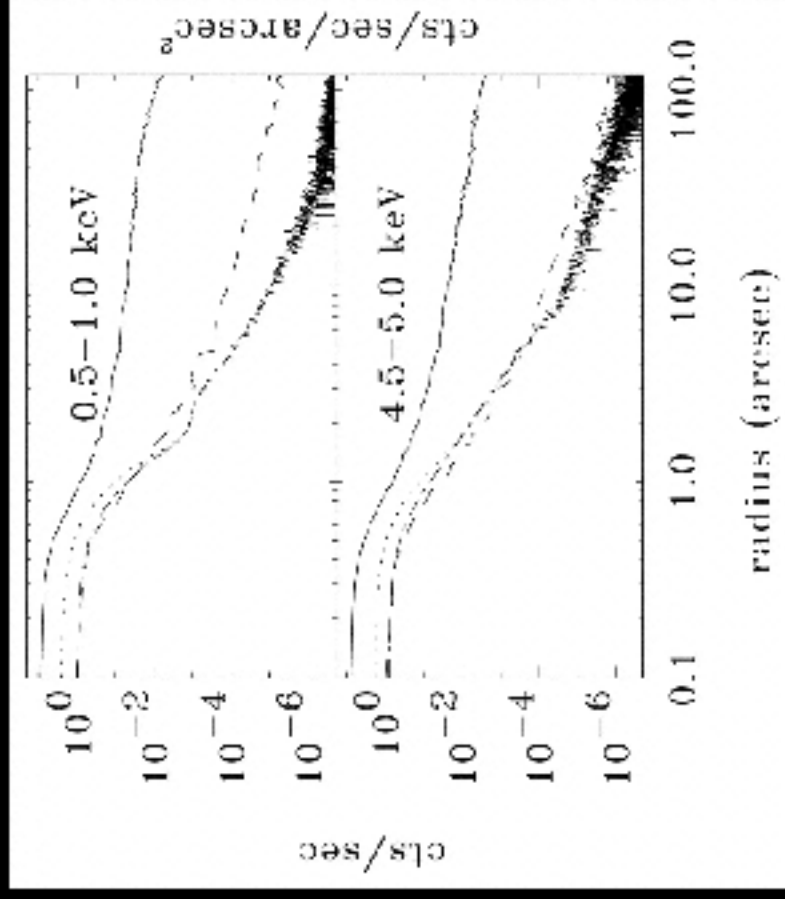
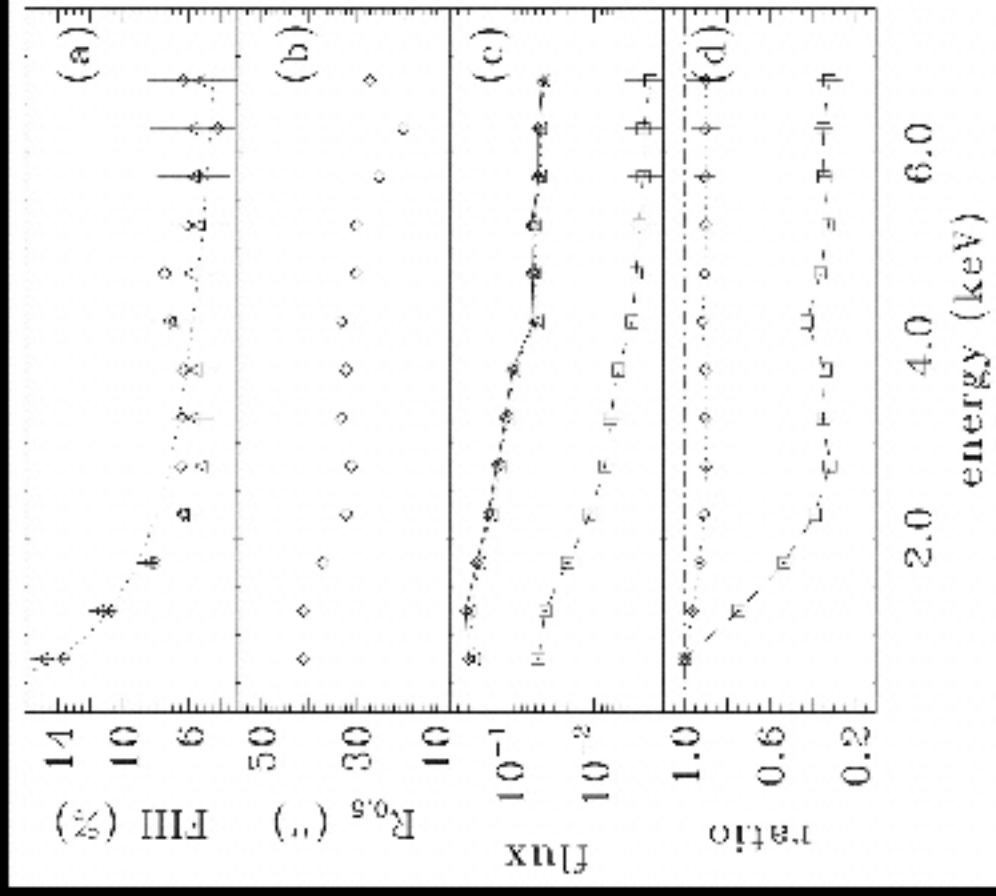
ACIS/HETG

Predehl et al 2000

X-ray Halo



X-ray Halo: Cygnus X-1

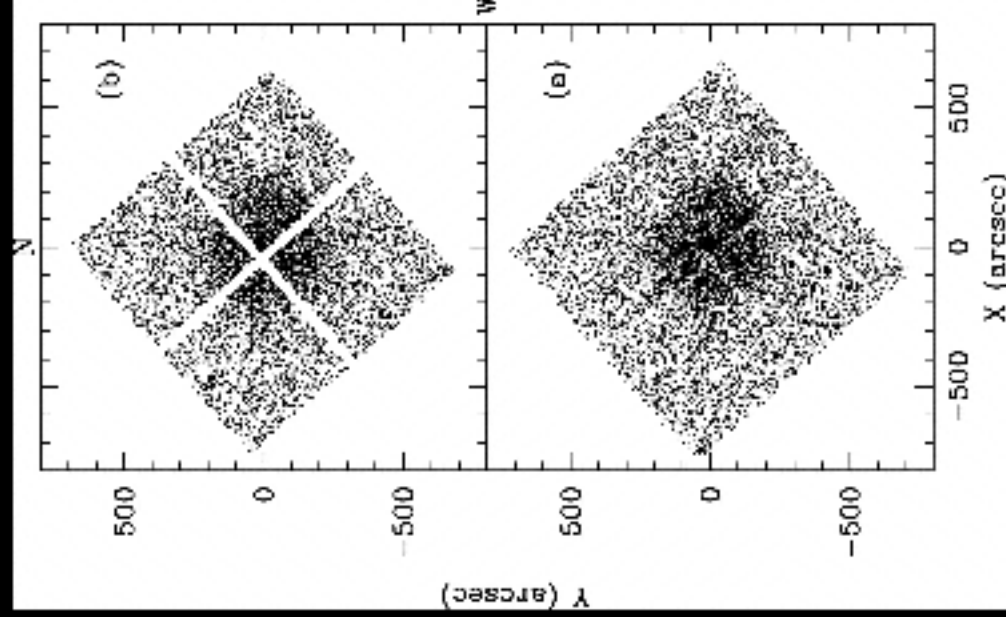


ACIS/HETG in CC

Yao et al 2003

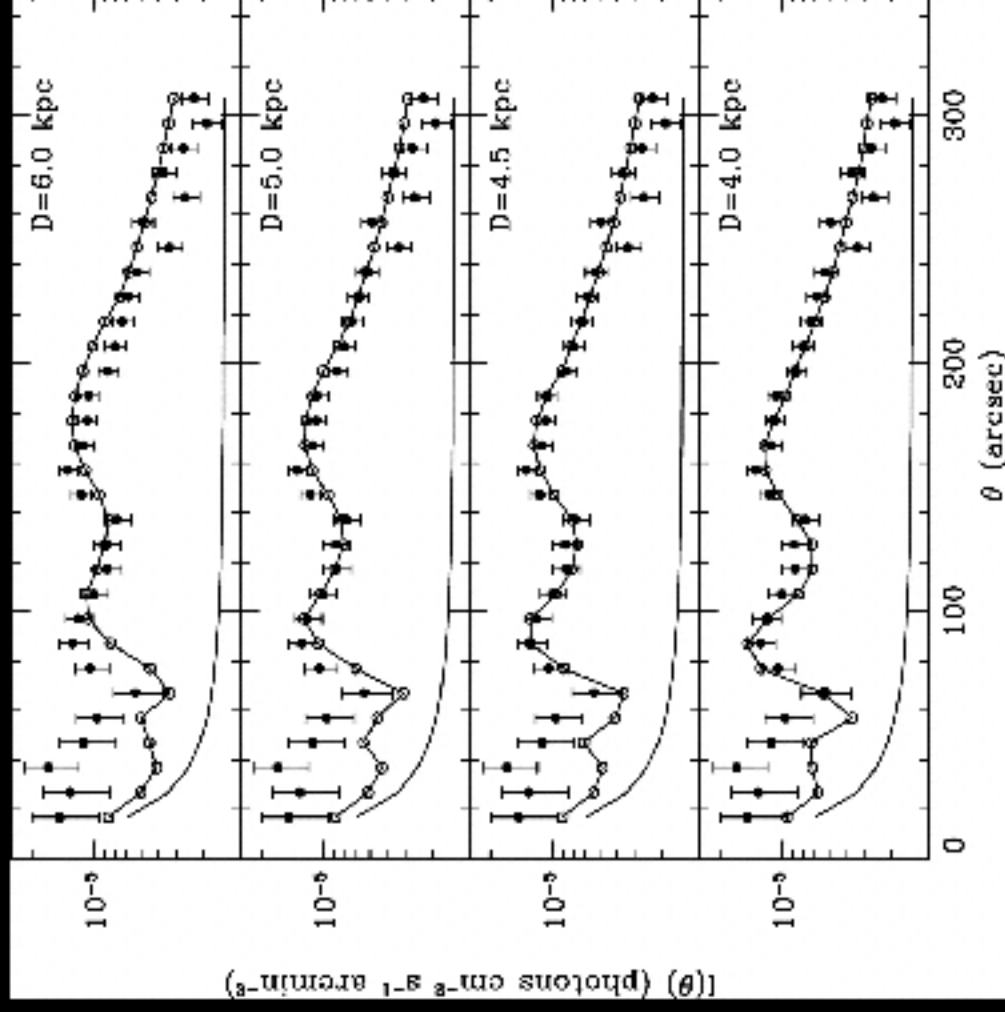
X-ray Halo: 4U1538-52

ACIS-I



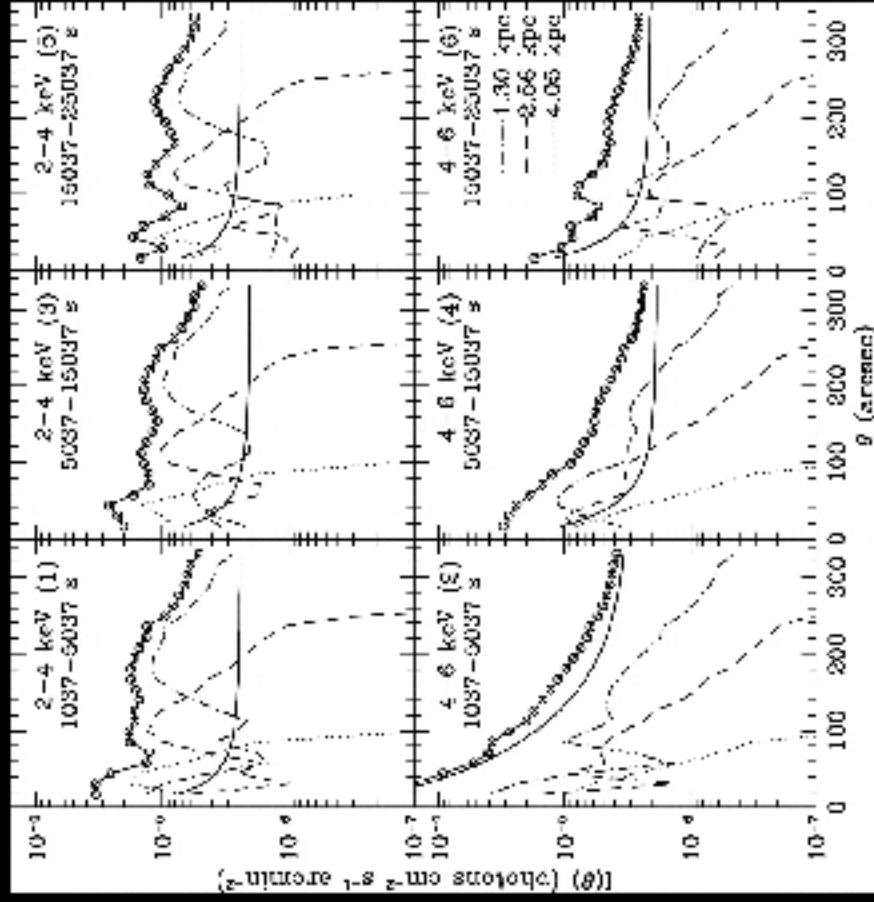
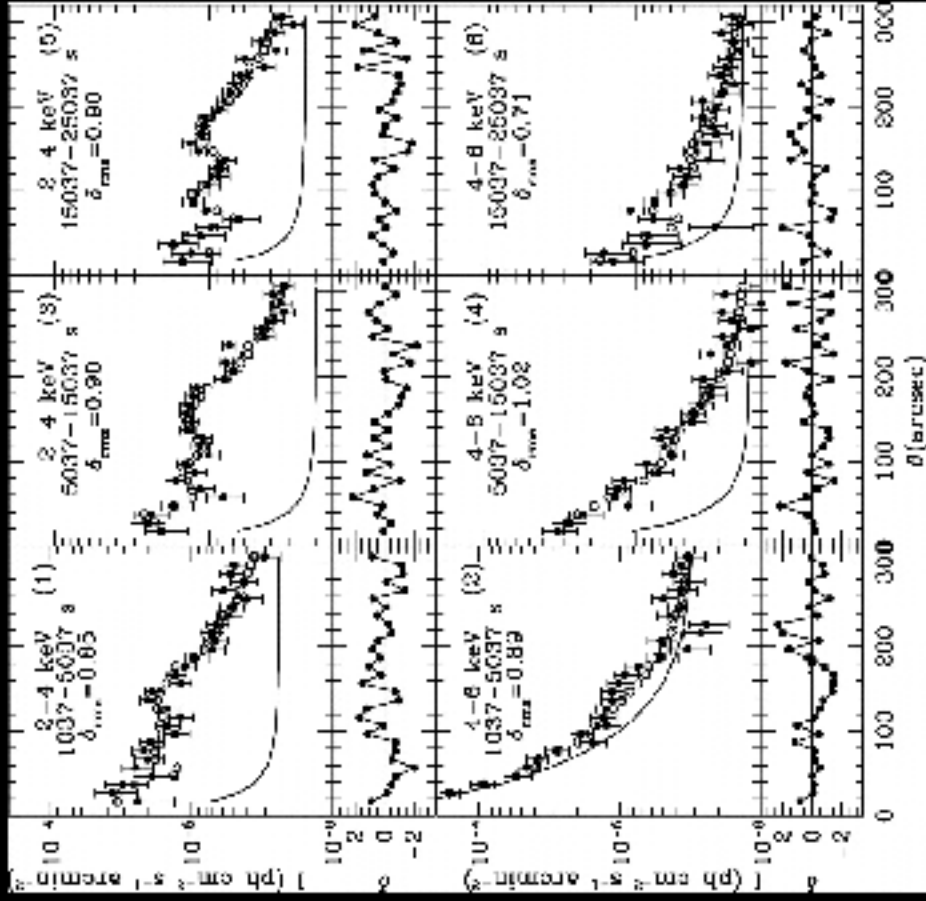
Clark 2004

X-ray Halo: 4U1538-52



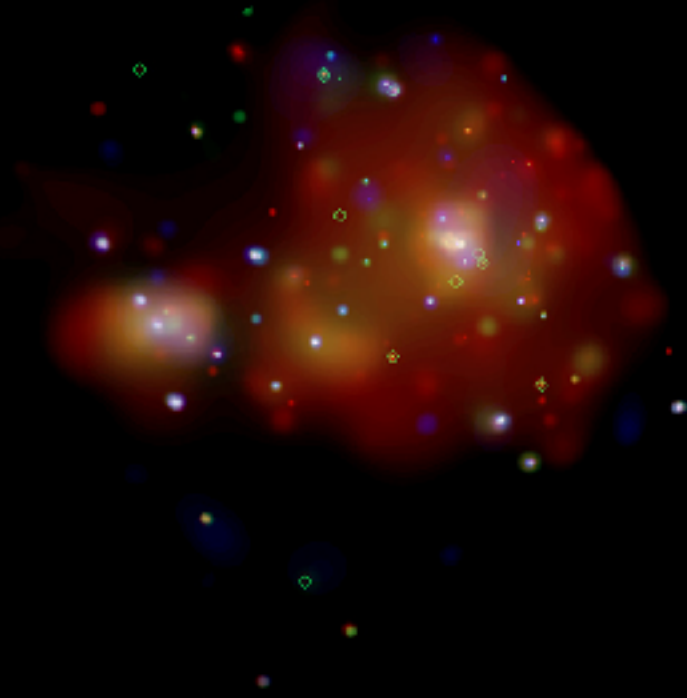
Clark 2004

X-ray Halo: 4U1538-52



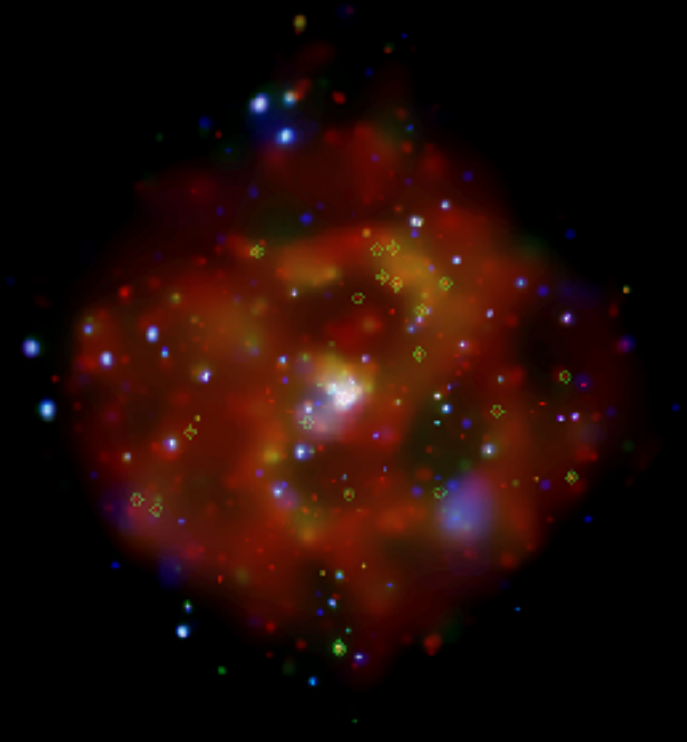
Clark 2004

Extragalactic X-ray Binaries



M51

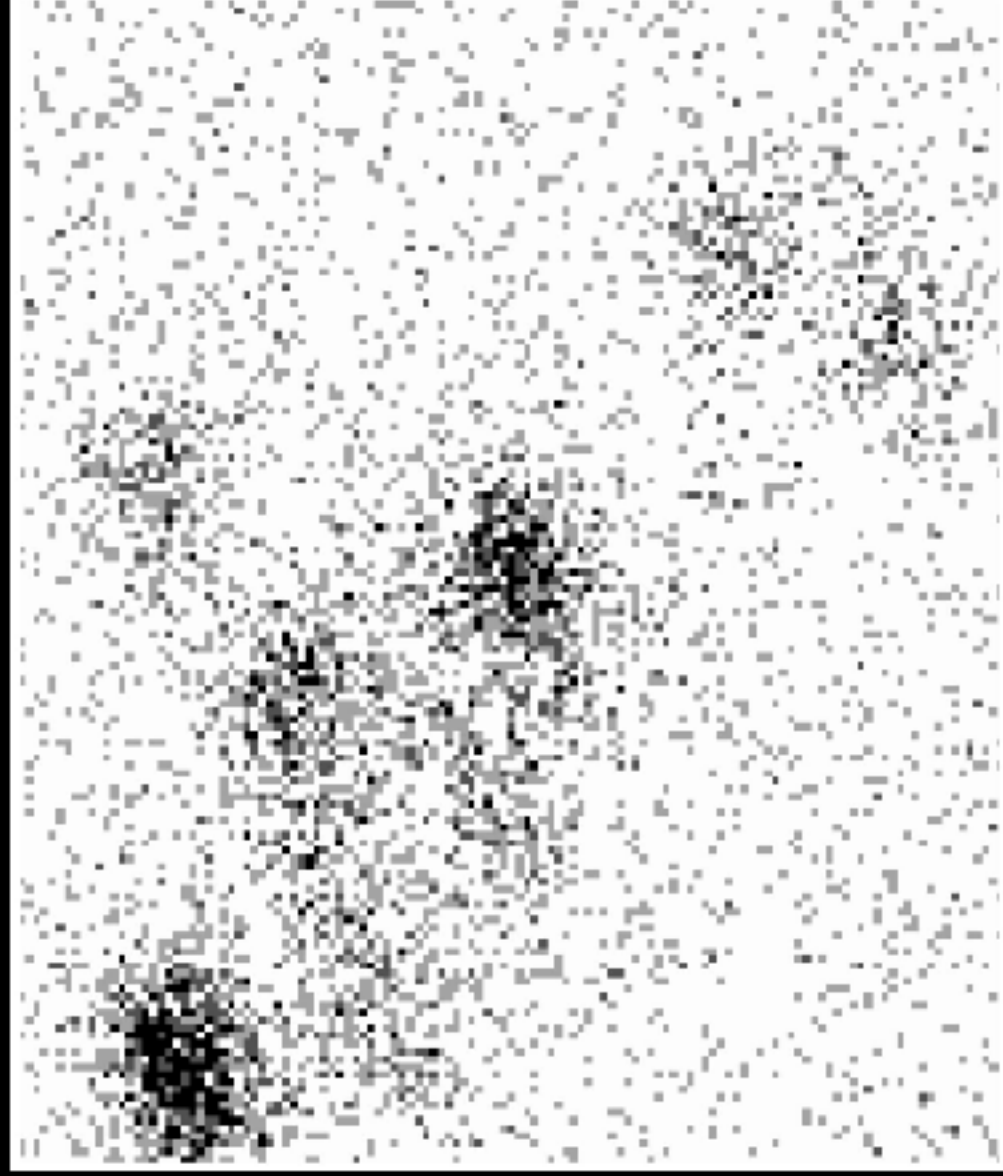
Wilson et al 2002



M83

Soria & Wu 2003

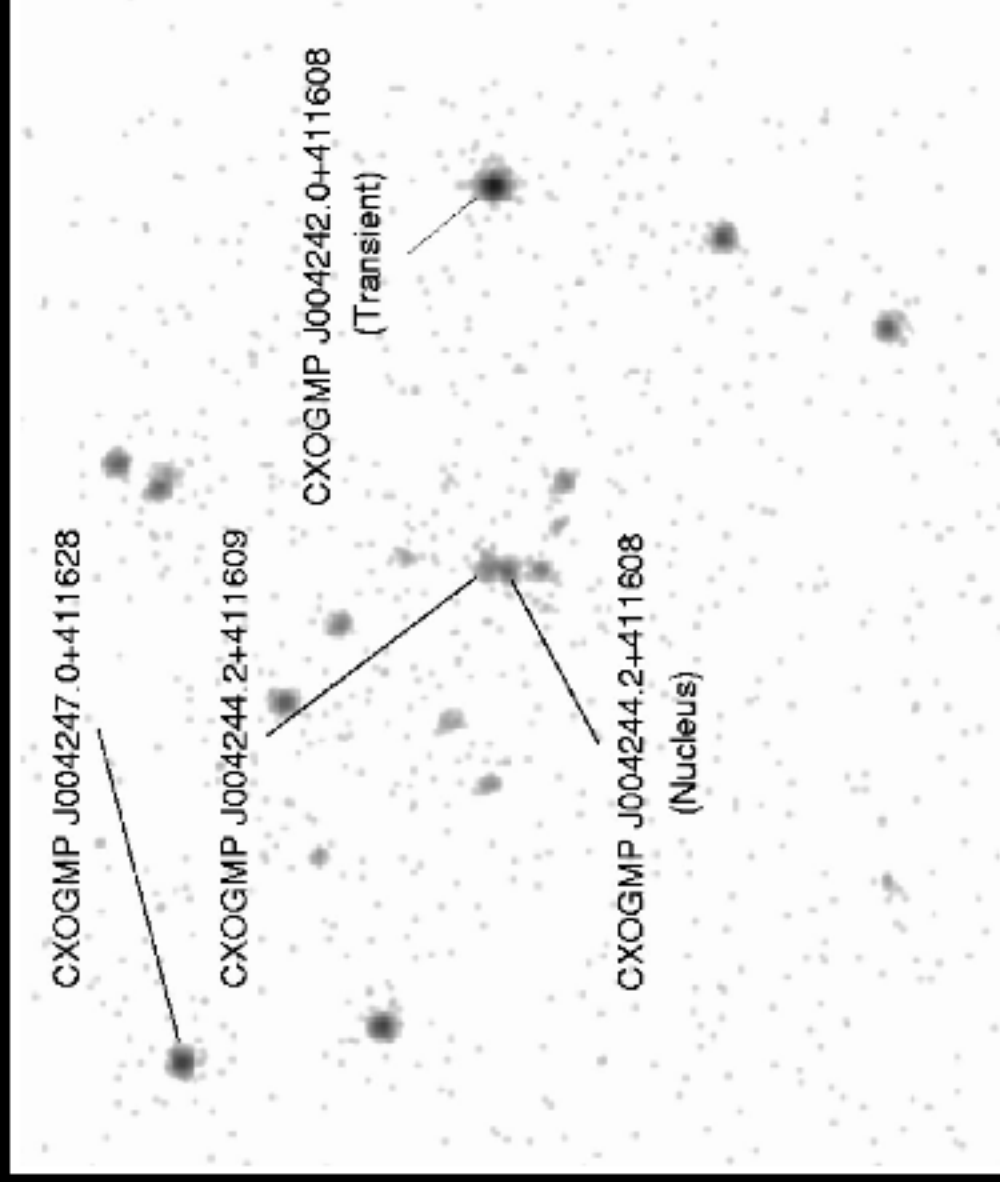
M 31: Old view!



ROSAT
PSPC

Garcia et al 2000

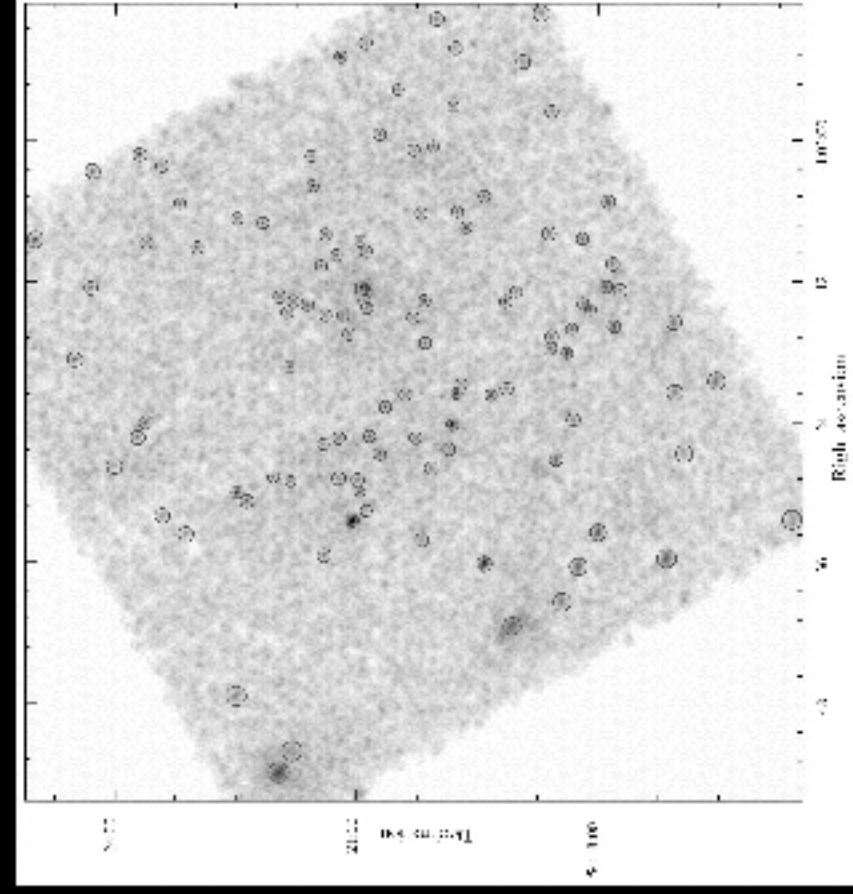
M 31: Chandra view!



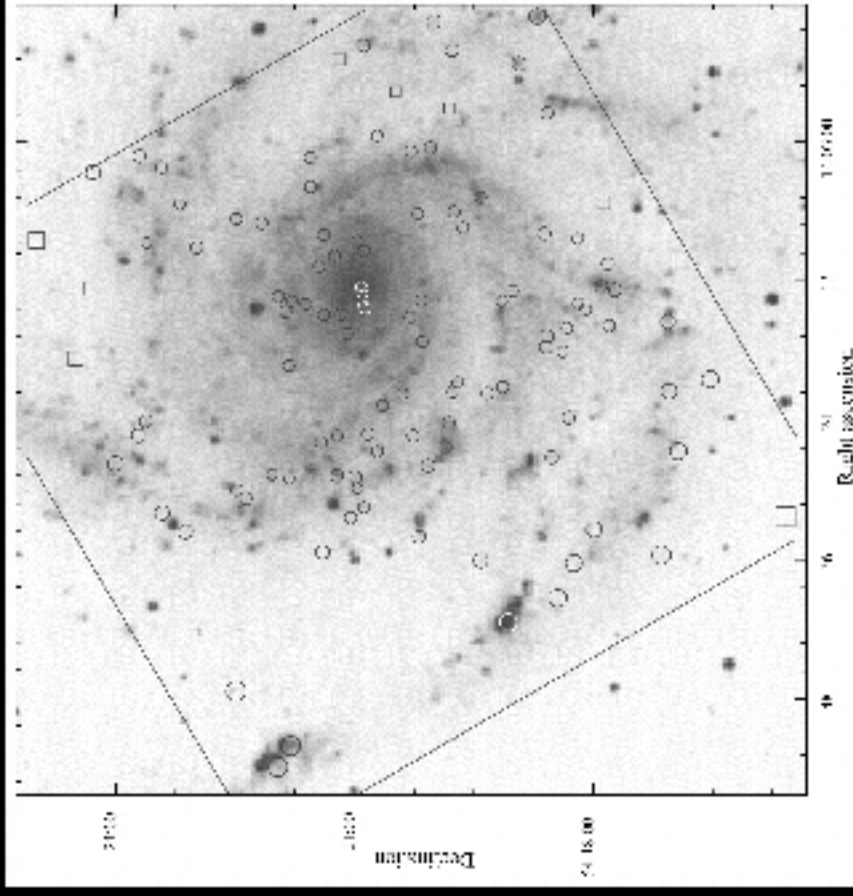
Chandra
ACIS-I

Garcia et al 2000

XRBS in M101

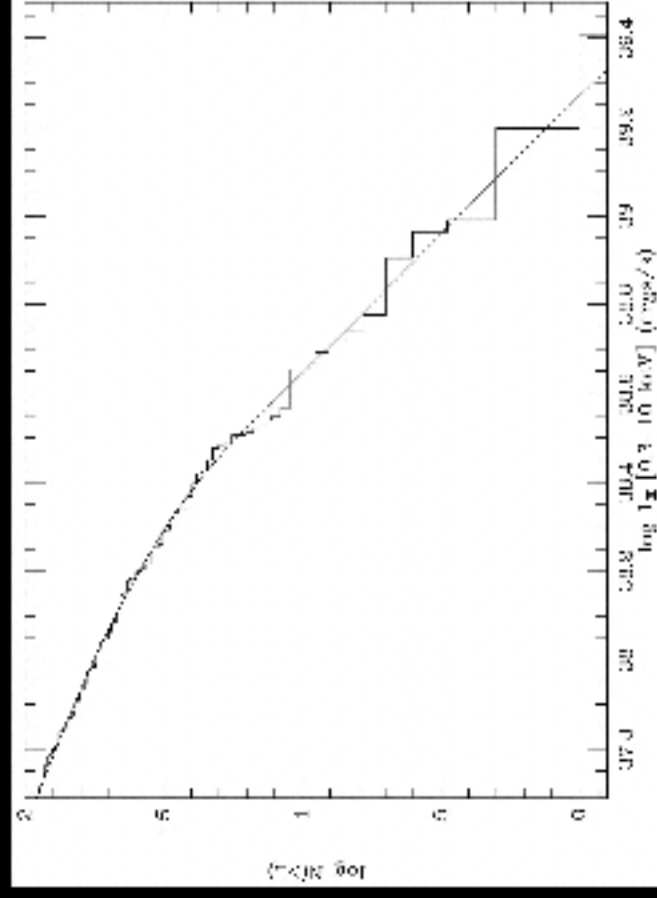
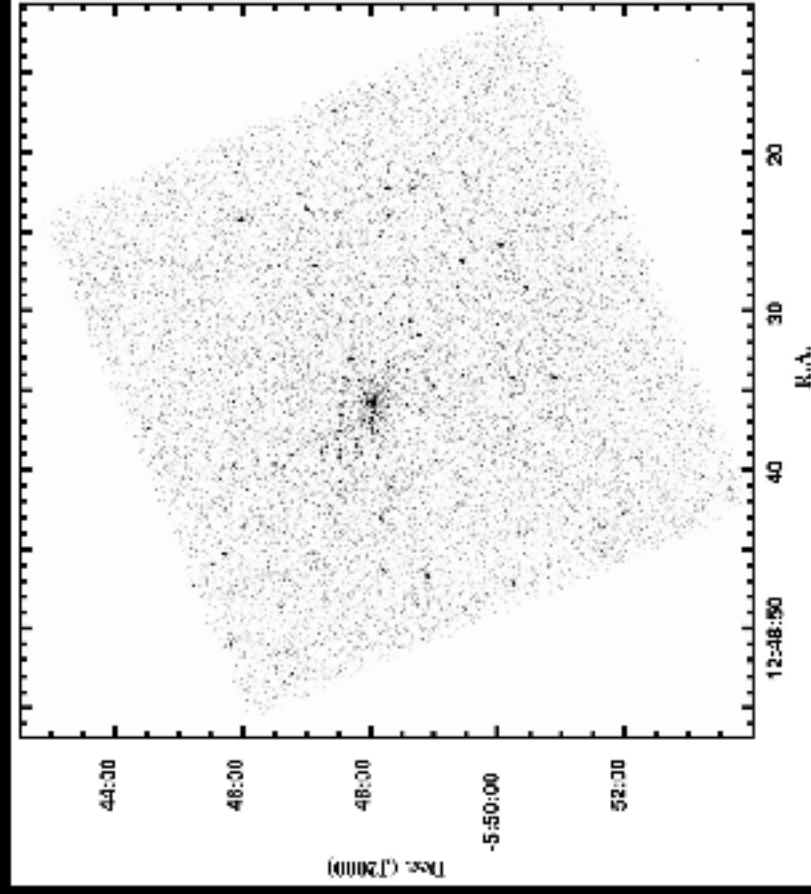


Chandra



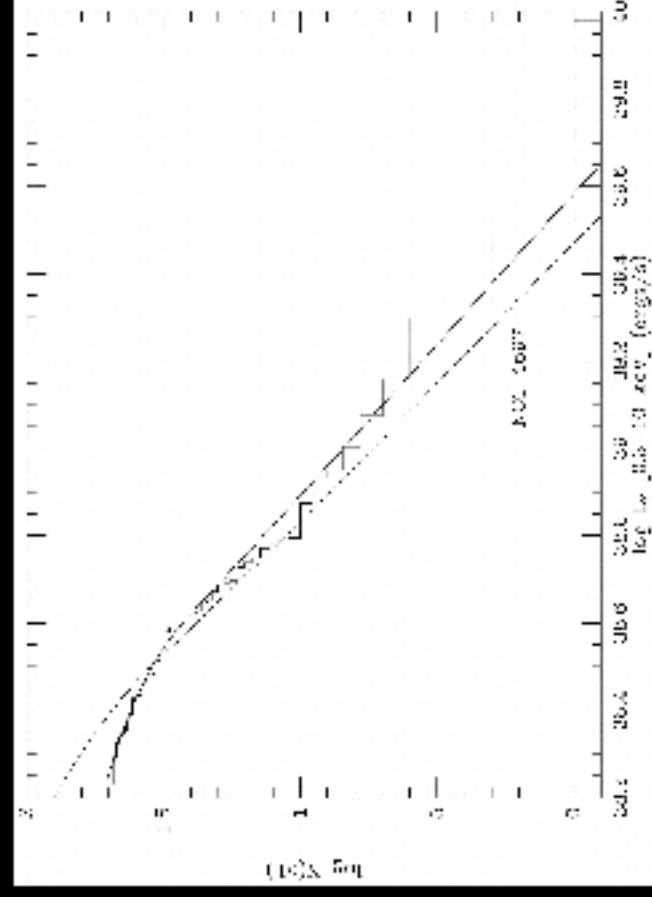
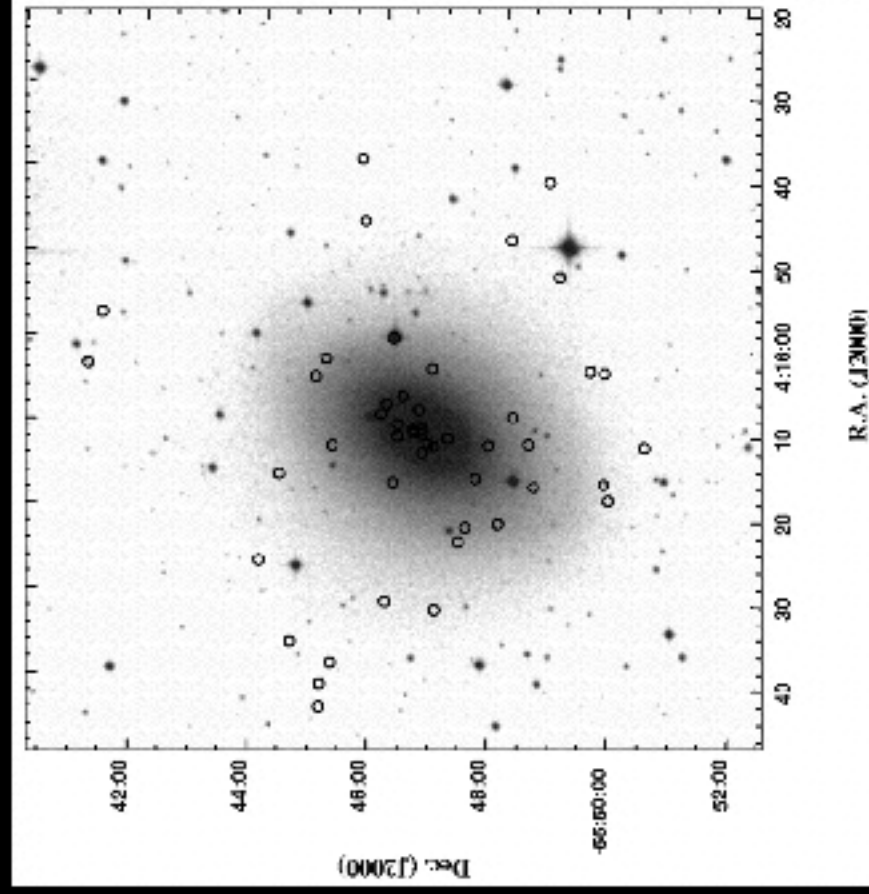
Pence et al 2001

Elliptical Galaxy NGC 4697



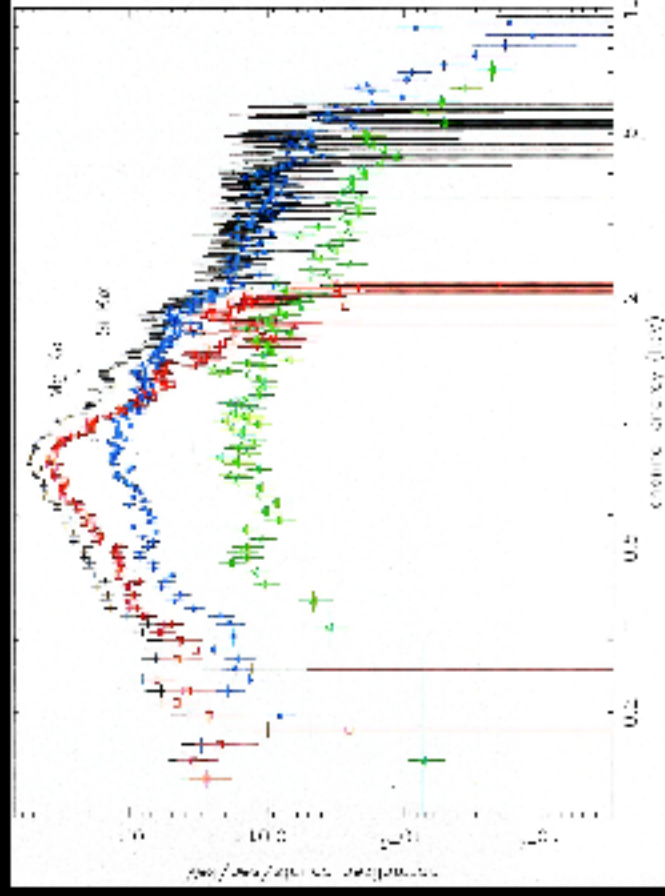
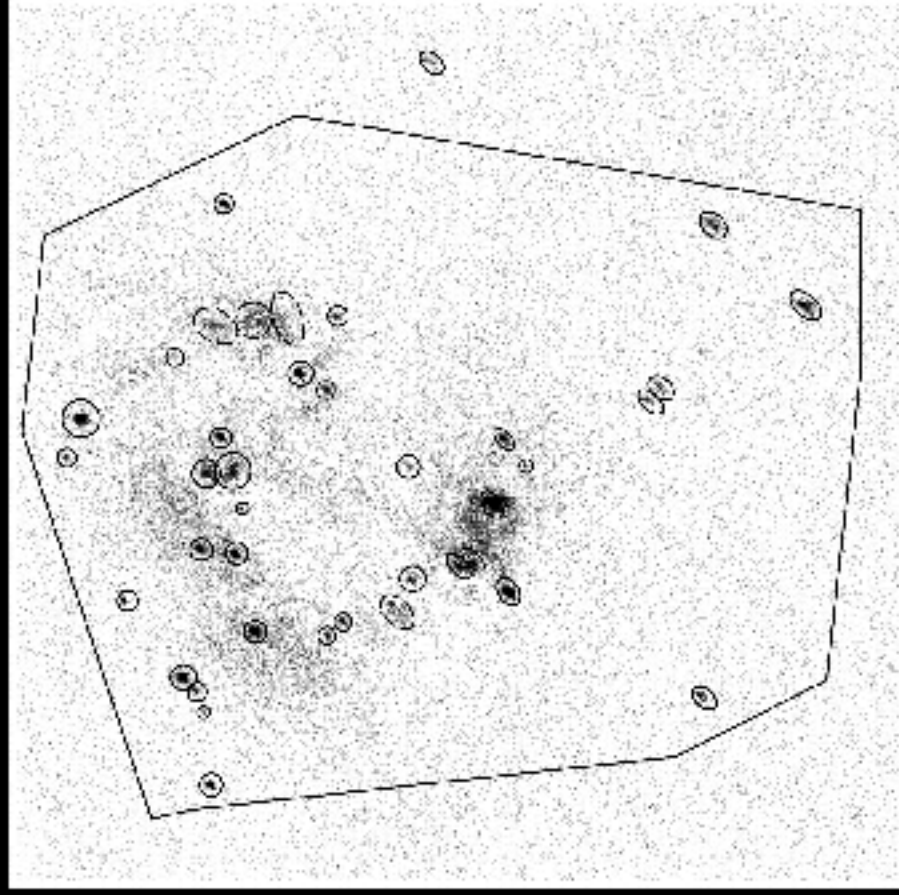
Sarazin, Irwin, & Bergman 2000

S0 Galaxy NGC 1553



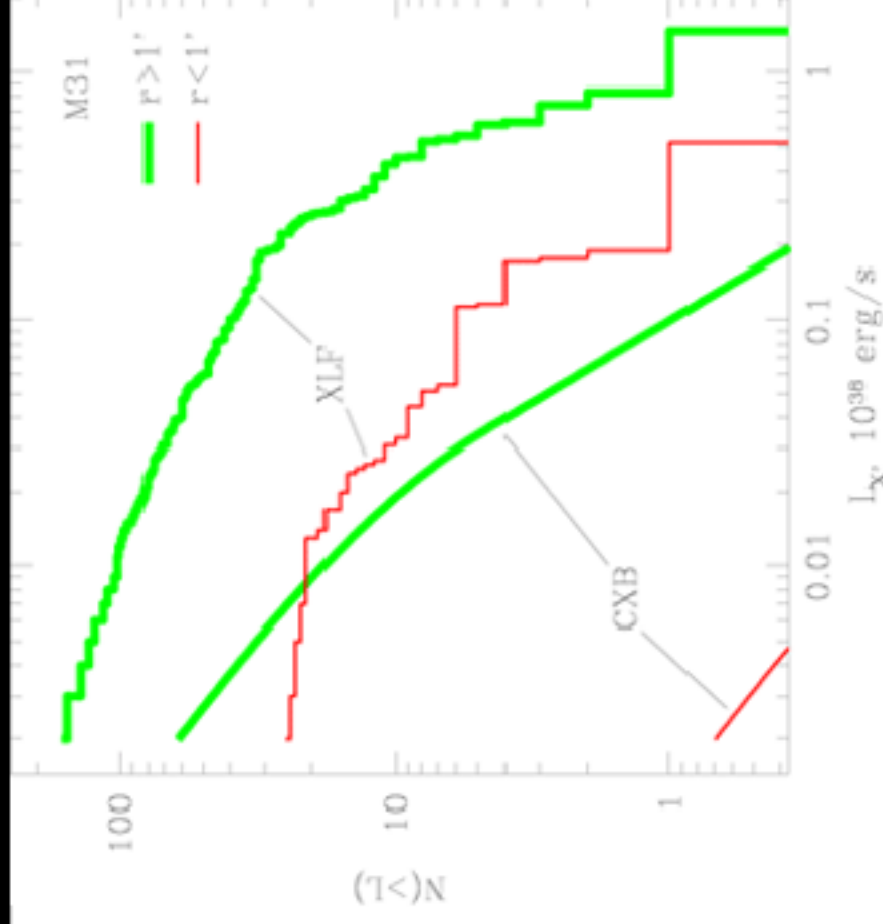
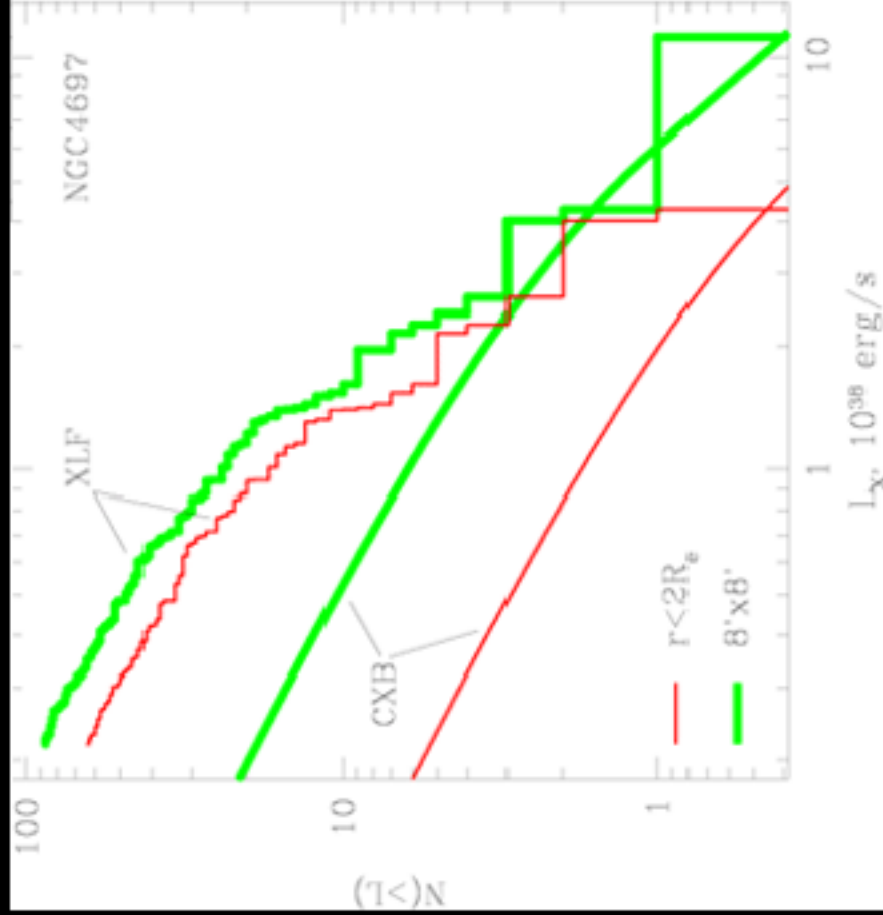
Blanton, Sarazin, & Irwin 2001

Colliding galaxies NGC 4038/39 ("the Antennae")



Fabbiano, Zezas, & Murray

CXB Contribution to XLF

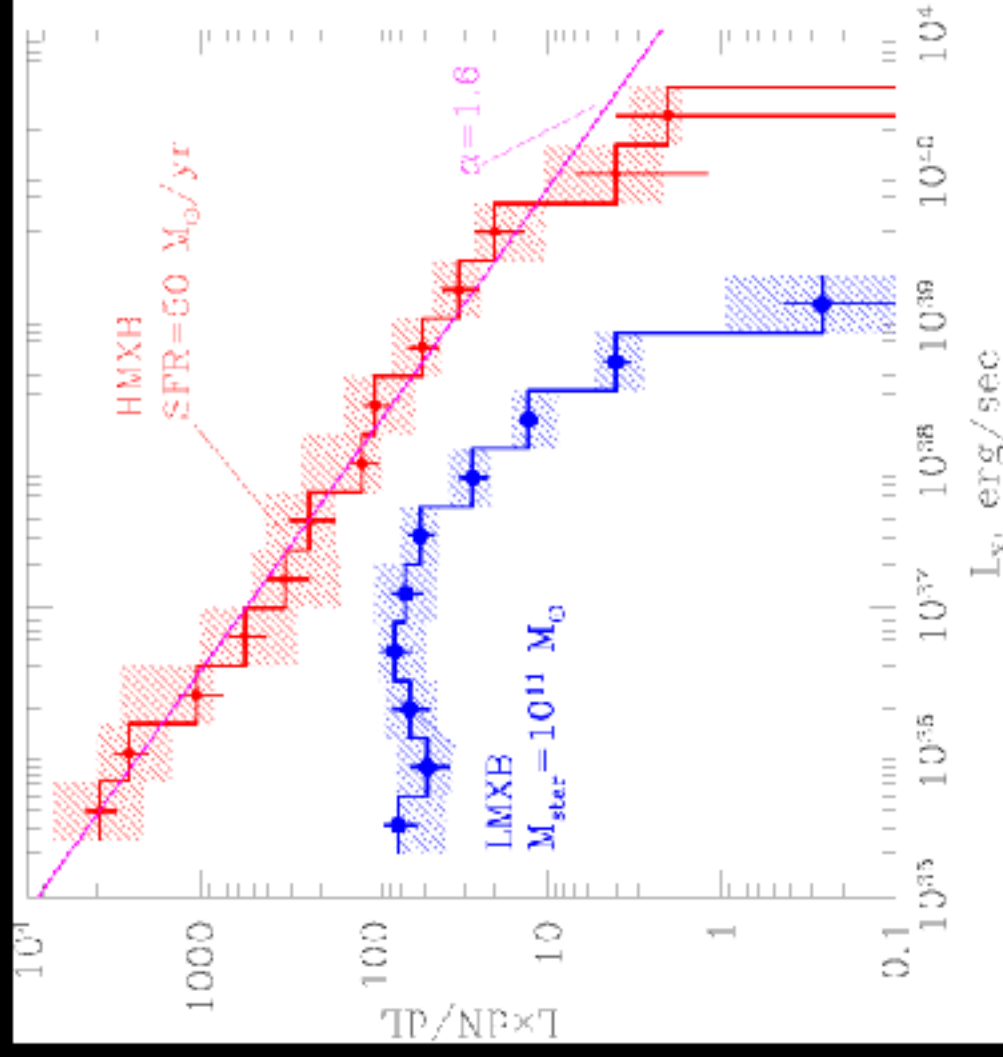


Sarazin et al 2001

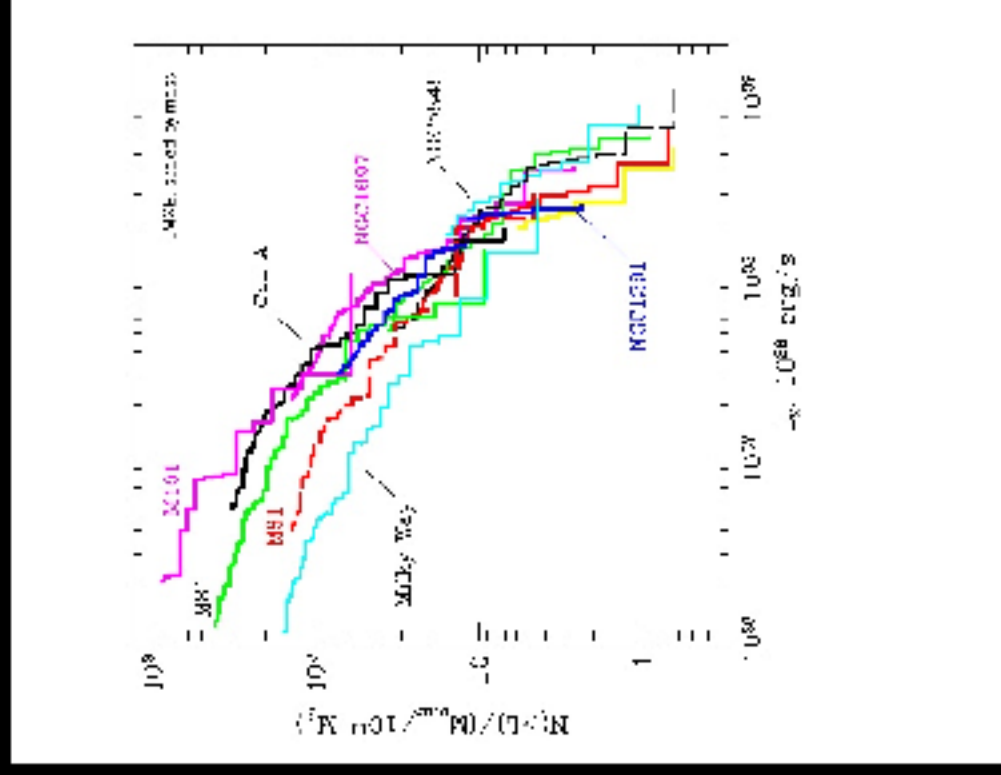
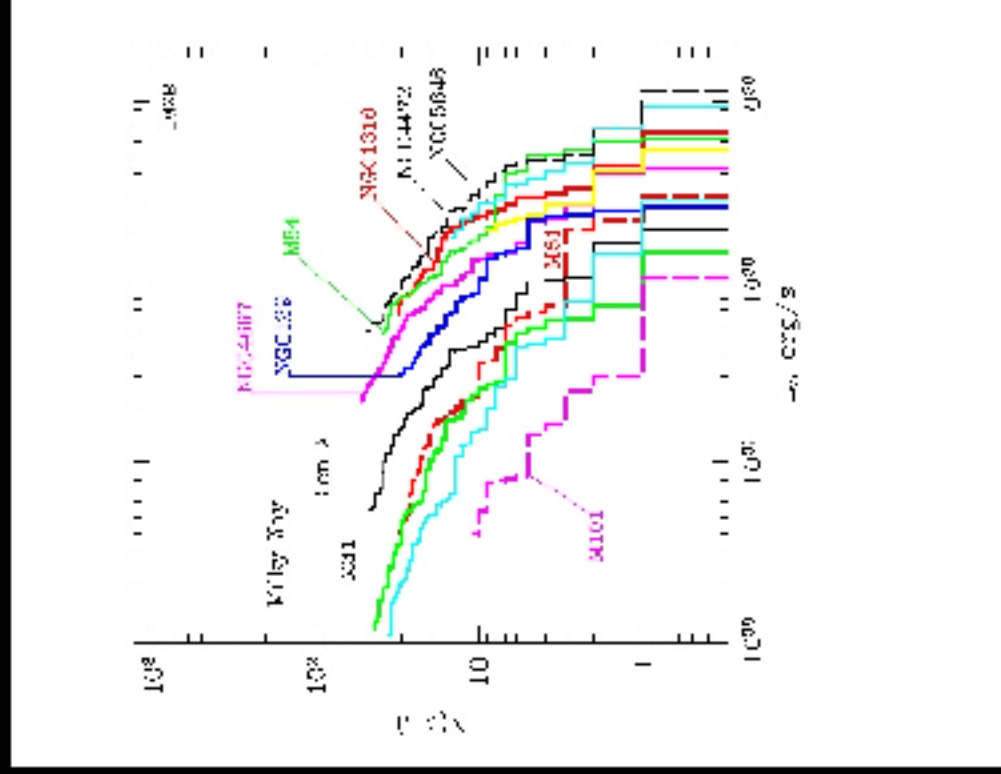
Gilfanov 2003

Kong et al 2002

“Universal” XLFs of HM and LM XBs

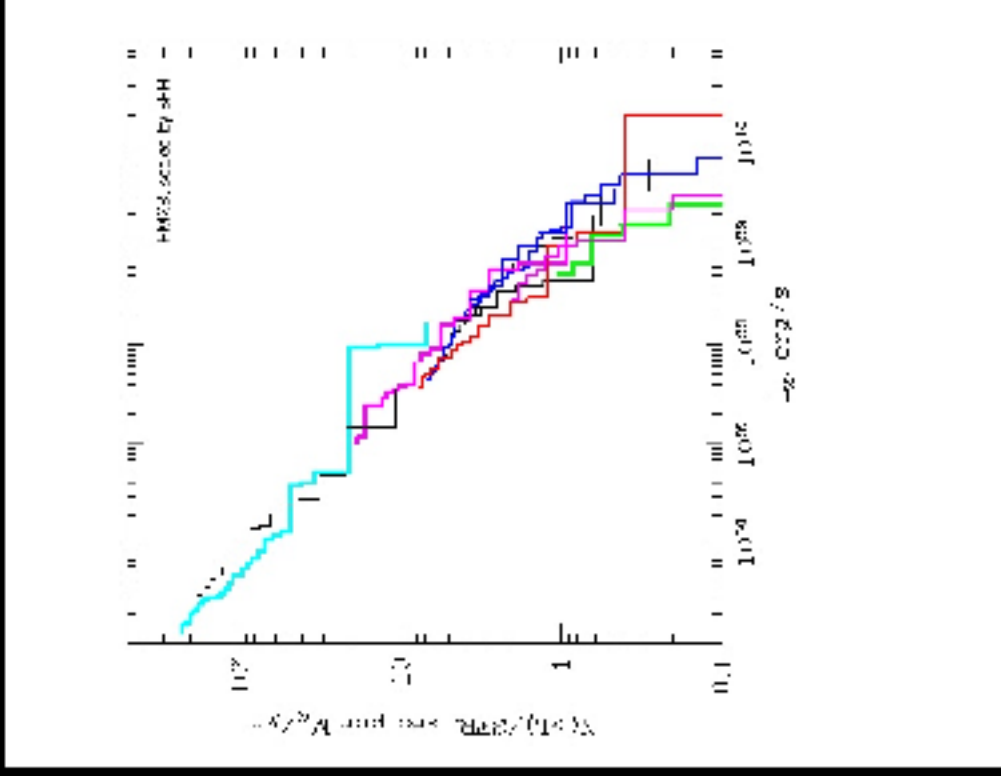
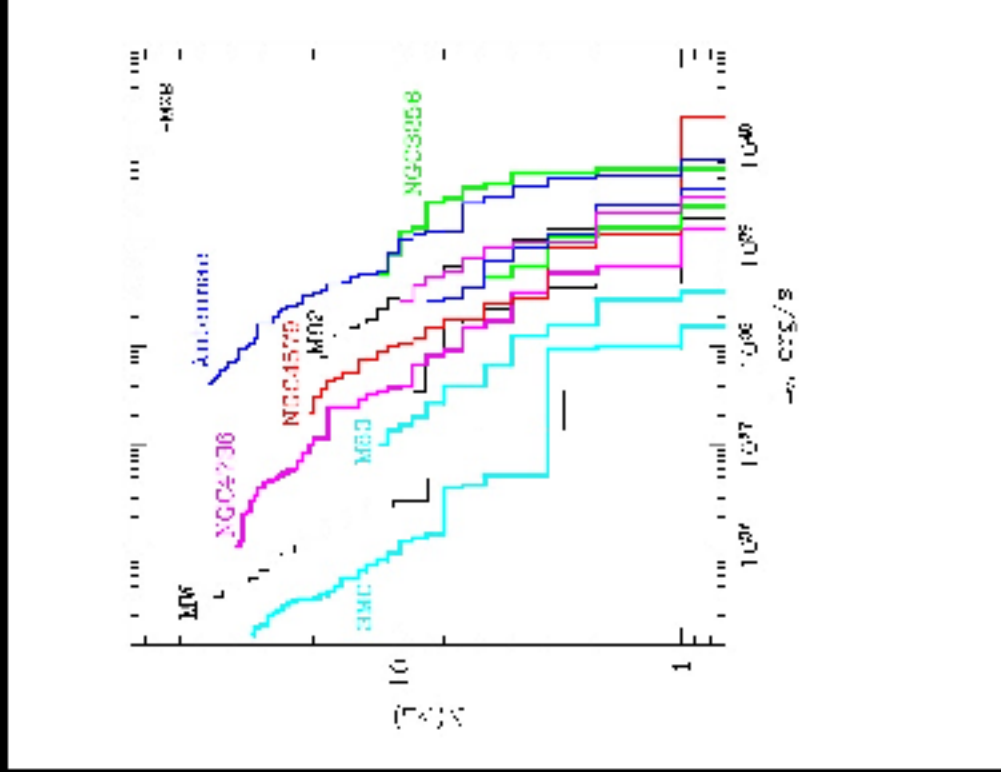


LMXB XLFs: Stellar Mass Indicators



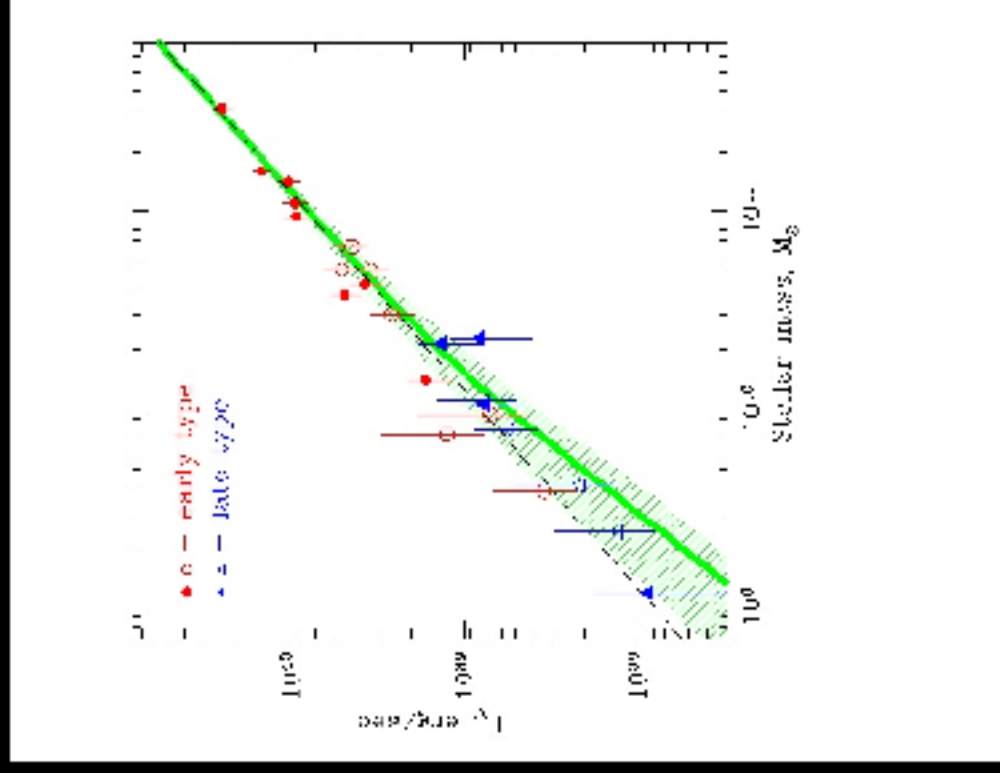
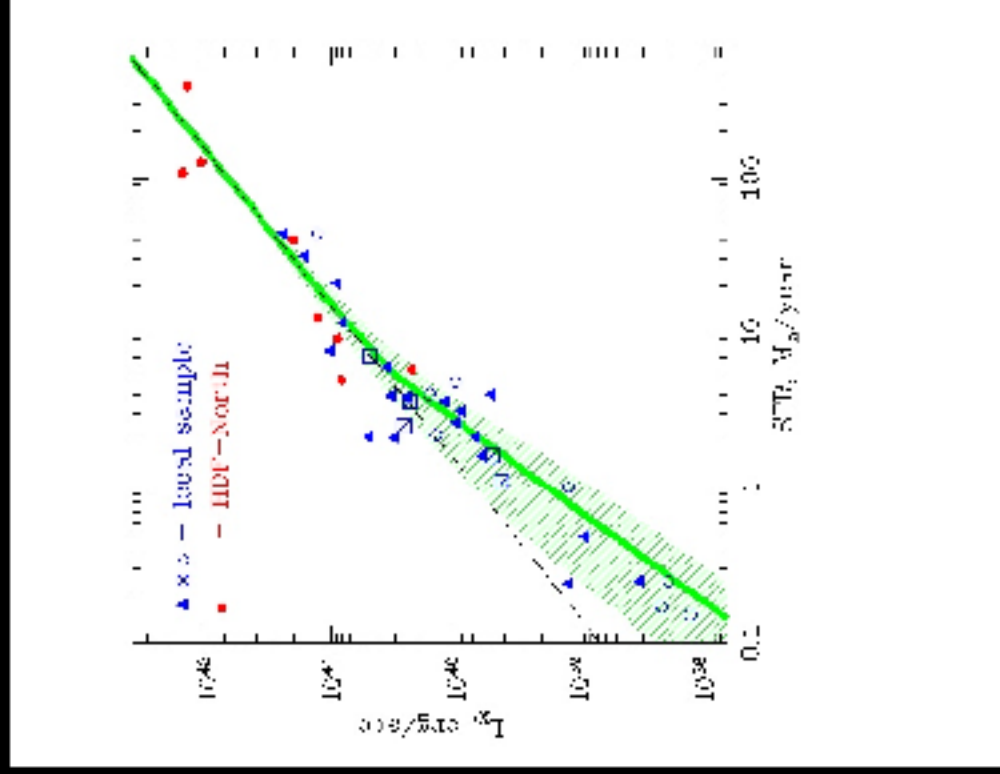
Gilfanov 2004

HMXBs: Star Formation Rate Indicators



Gilfanov 2004

L_X -SFR and L_X - M_*



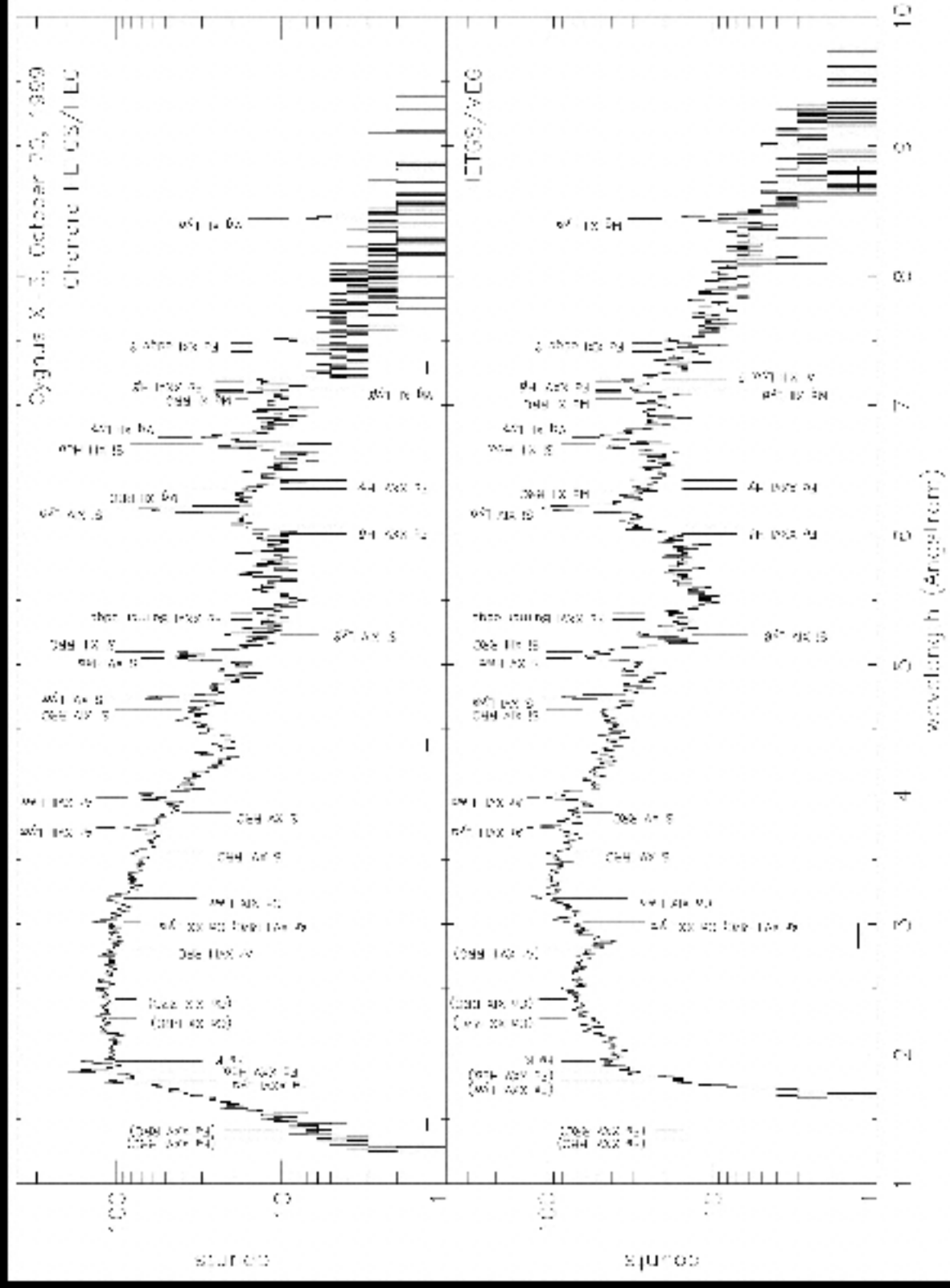
Grimm et al 2003; Gilfanov 2004

The Chandra View

- Spectral

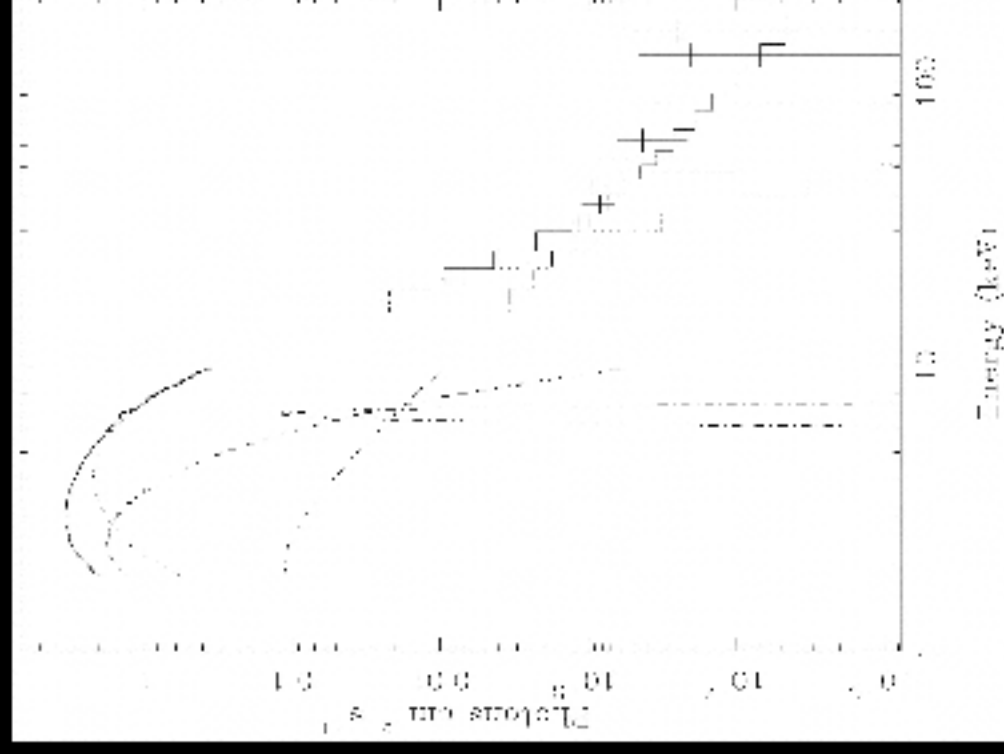
Elements and Abundances
X-ray line velocities

Cyg X-3 with Chandra HETG



Paerels et al 2000

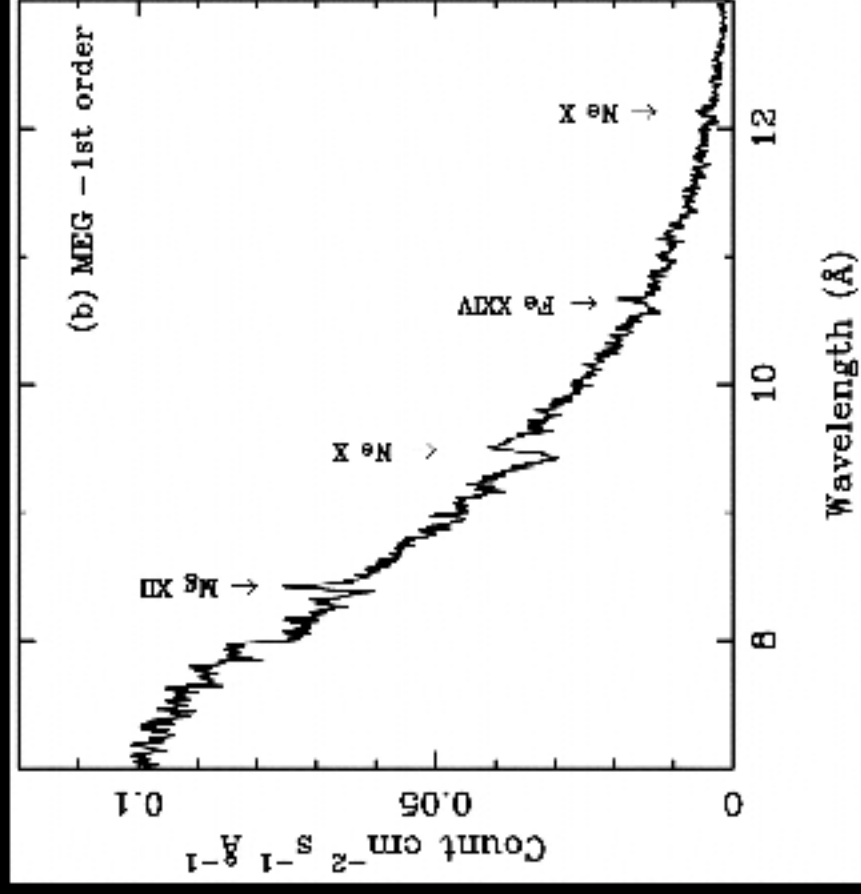
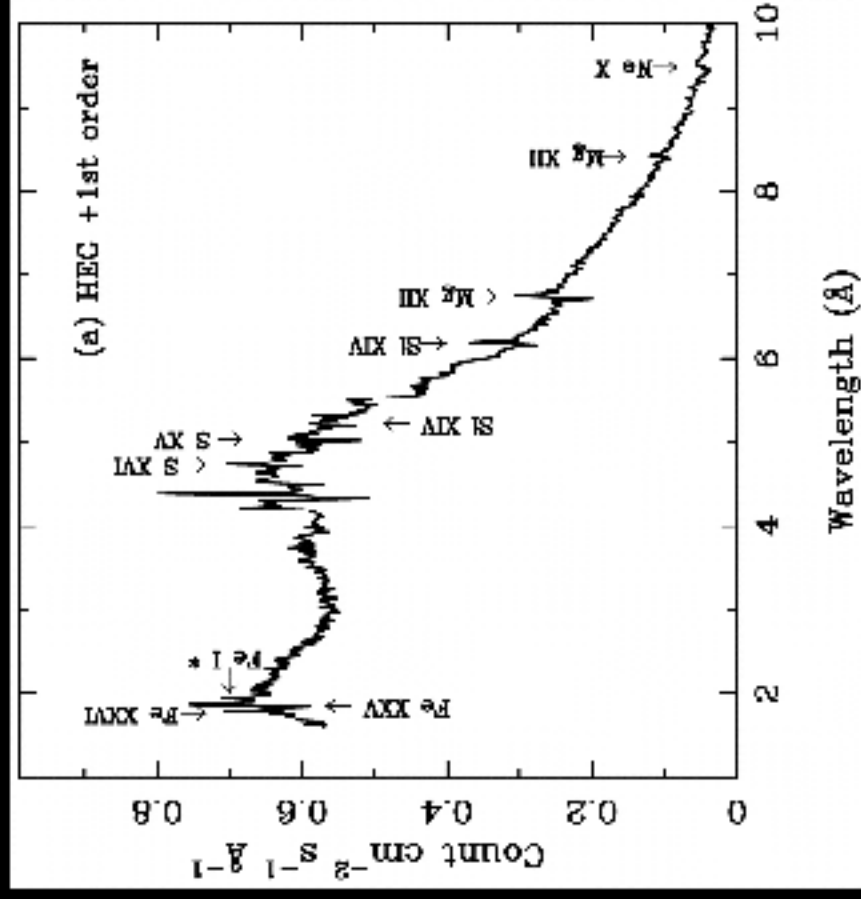
Circinus X-1



BeppoSAX

laría et al 2002

Circinus X-1: X-ray P-Cygni!



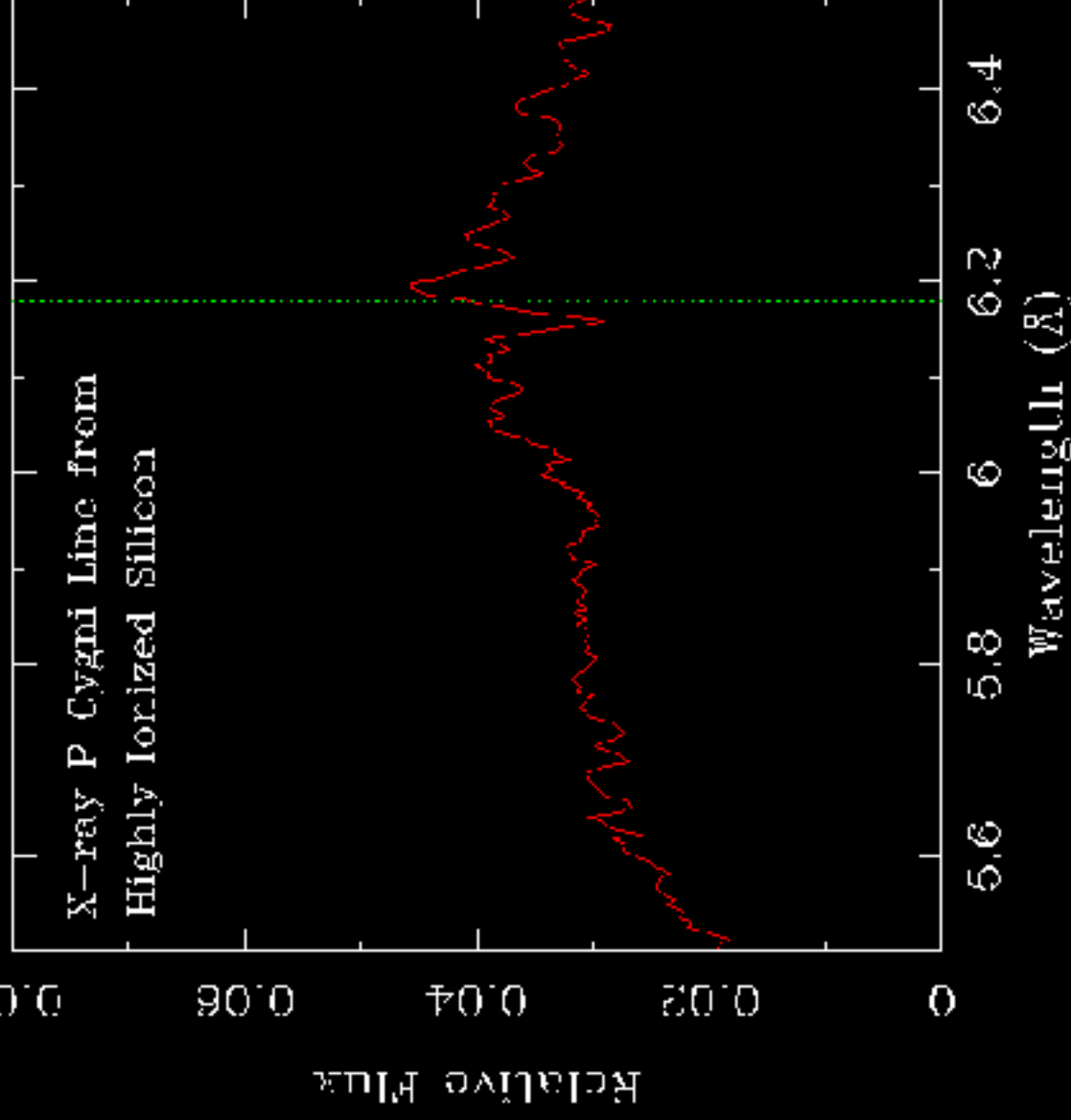
ACIS/HETG

Schulz et al 2000

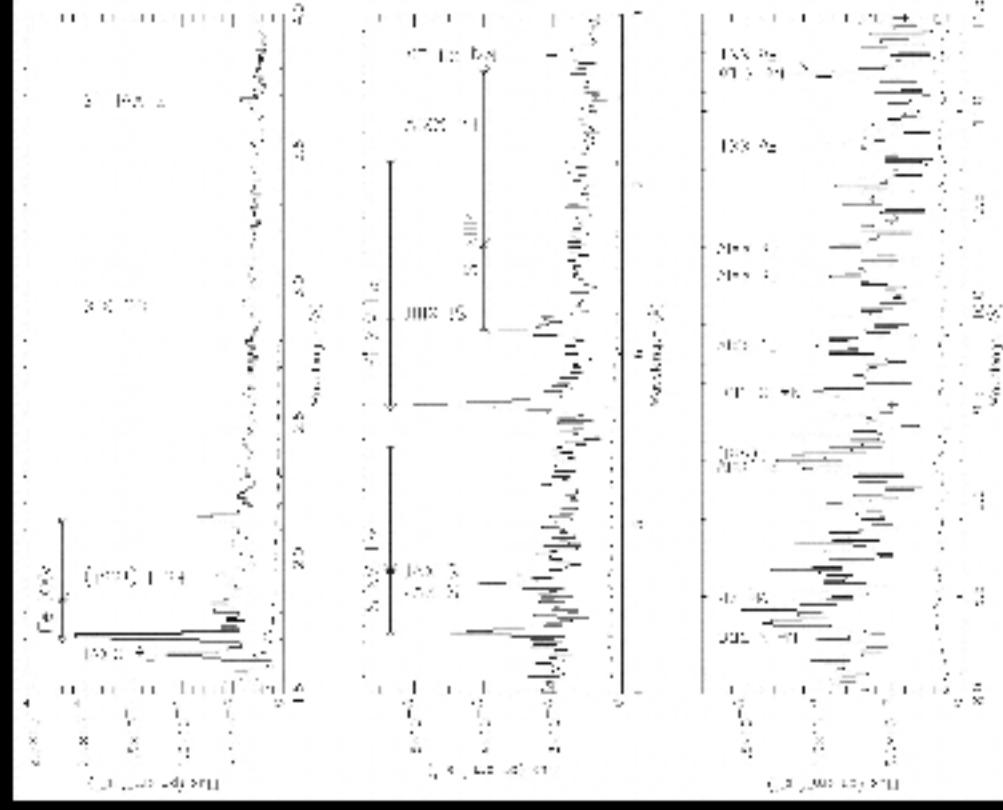
Time variability of a P Cygni Line

Time step: 1

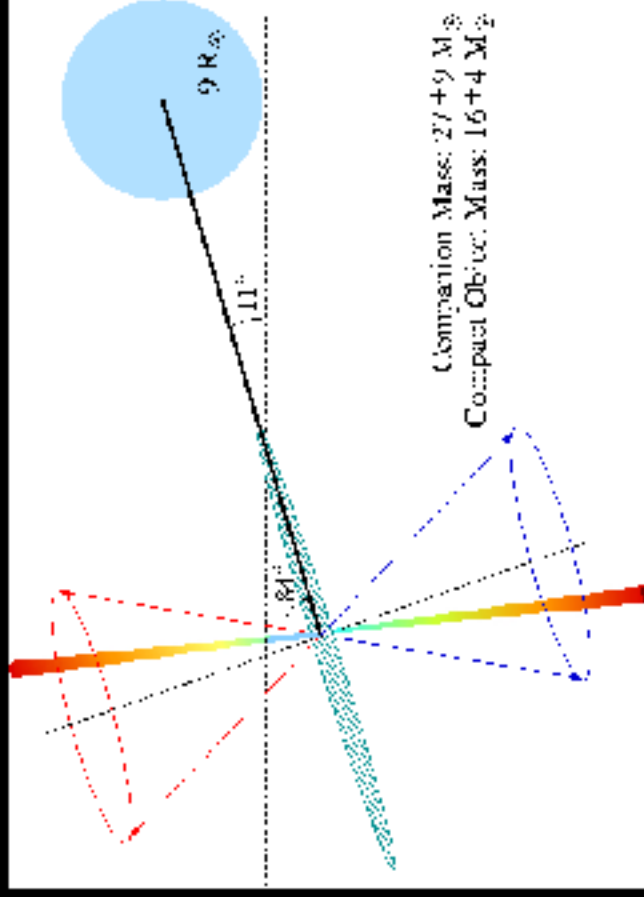
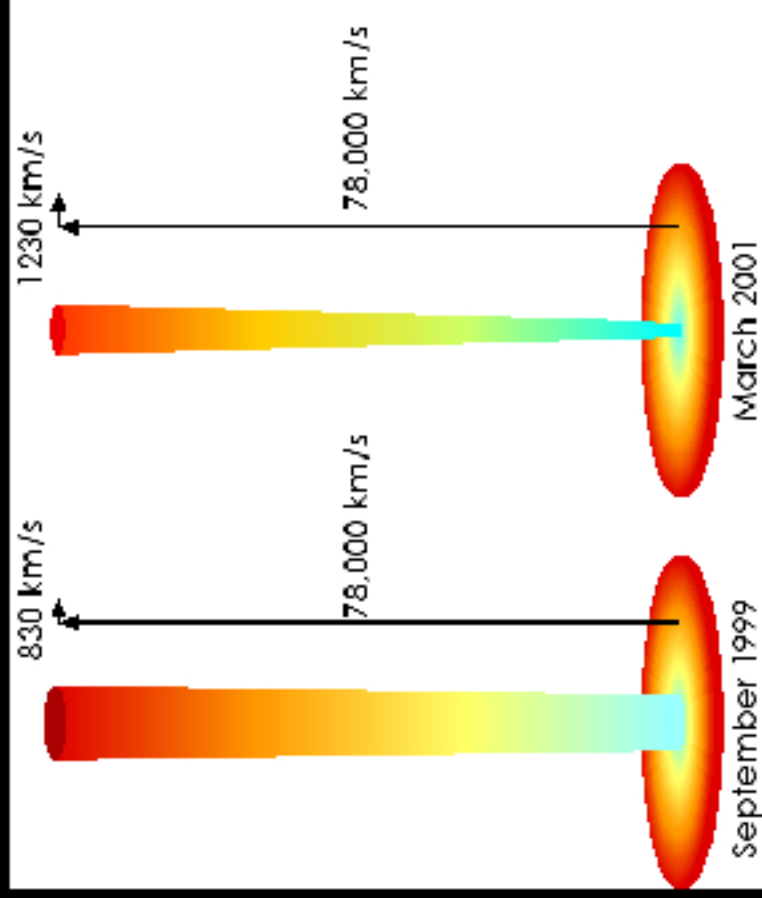
X-ray P Cygni Line from
Highly Ionized Silicon



SS433 with HETG

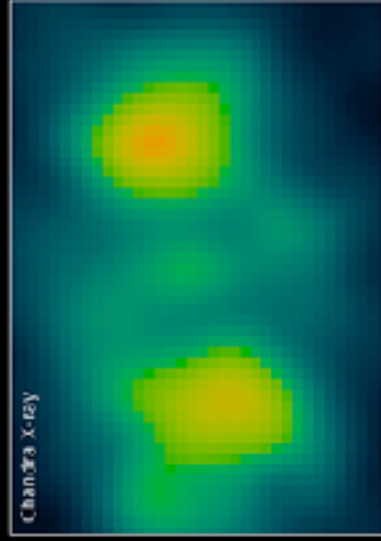


SS433 Model

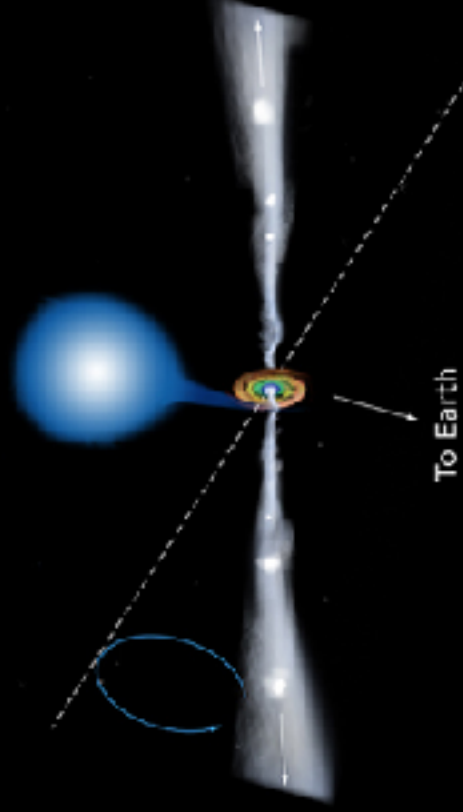


Marshall et al 2003

SS433

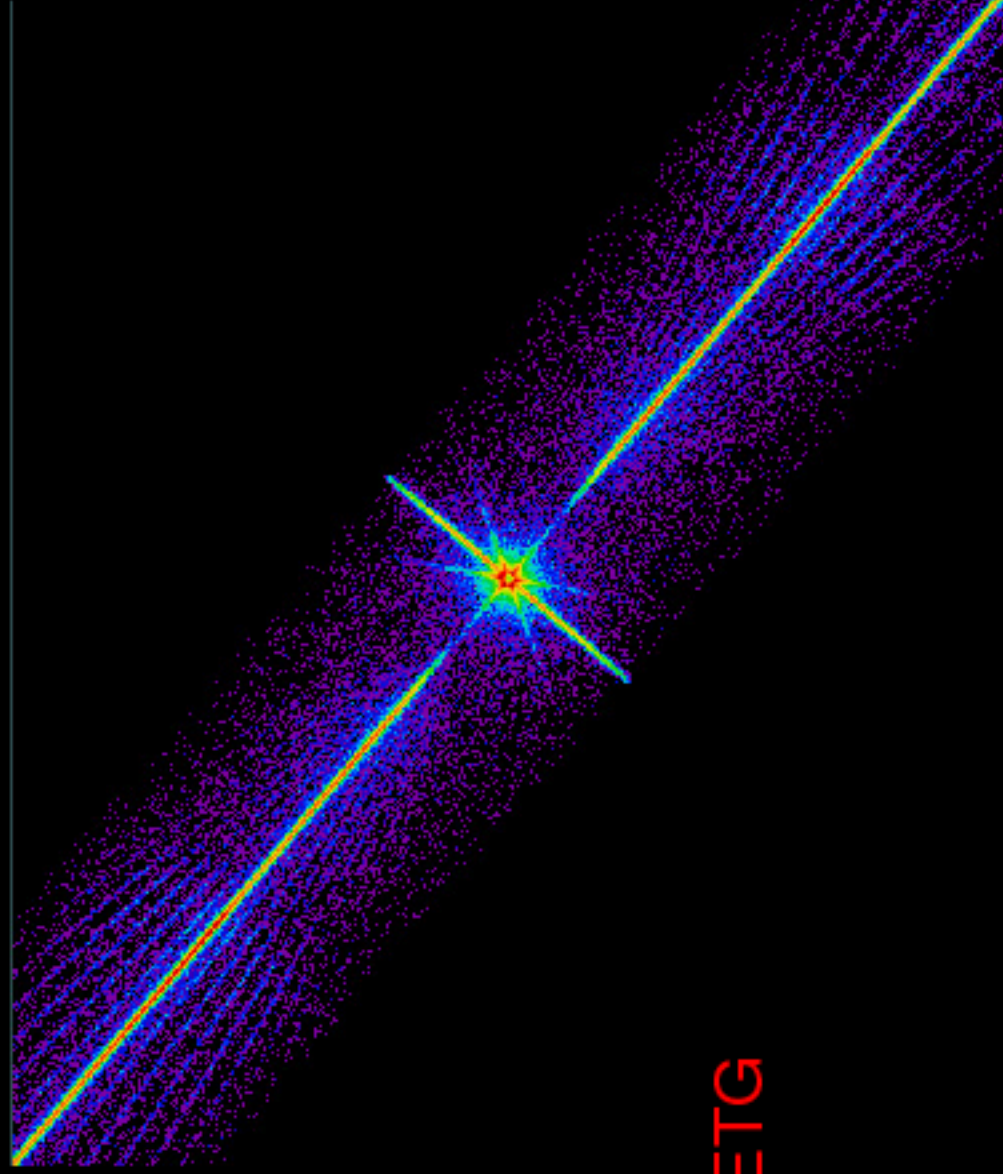


Chandra ACIS



Migliari et al 2002

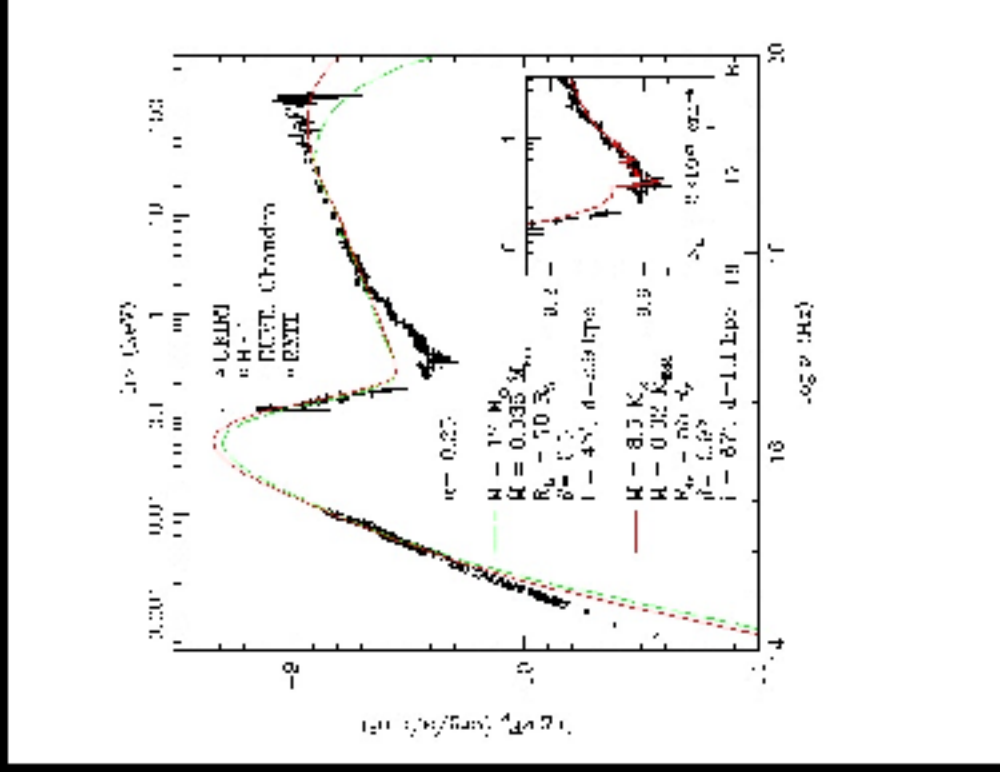
XTE J1118+480



Chandra LETG

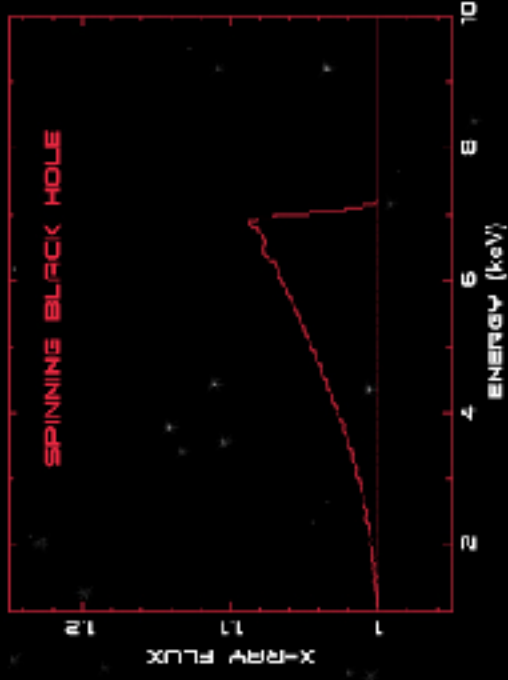
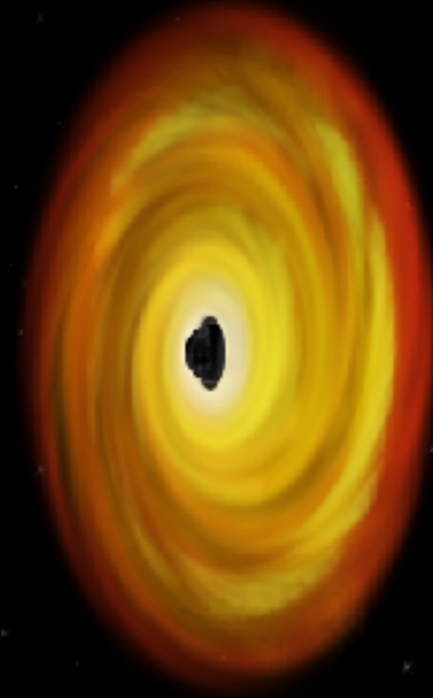
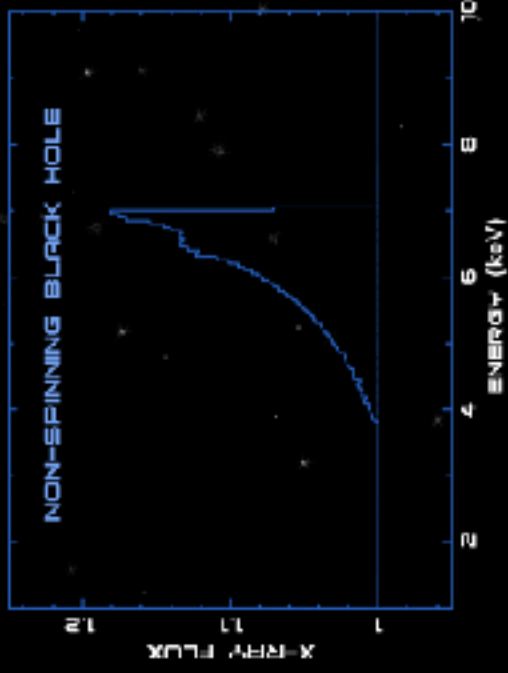
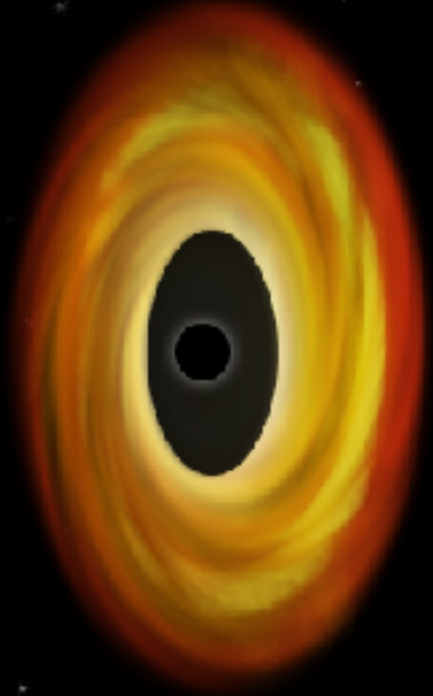
McClintock et al 2001

XTE J1118+480



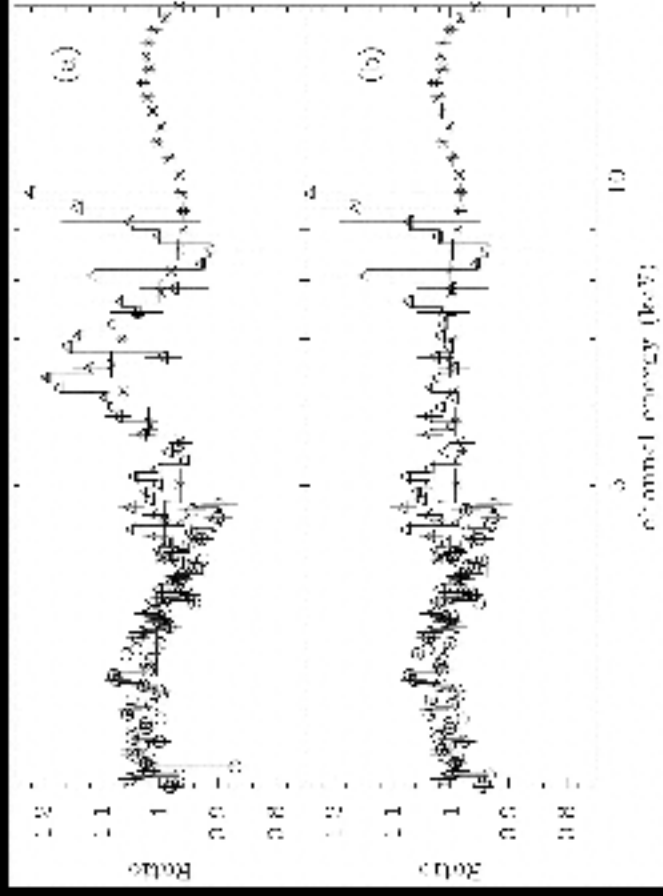
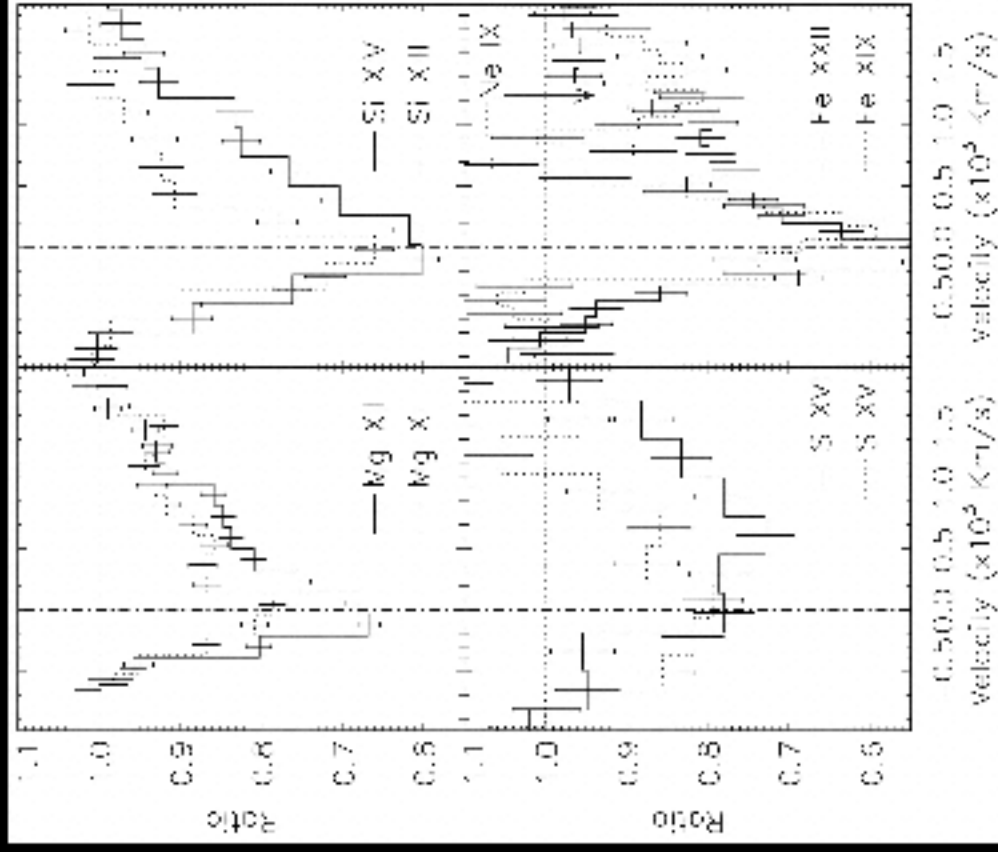
Esin et al 2001

Relativistic Fe Lines



Miller et al 2003

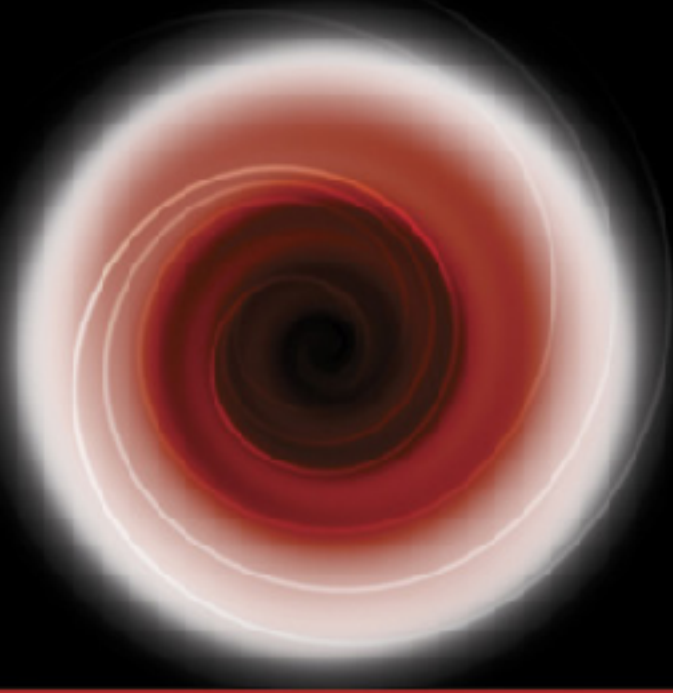
Cyg X-1 with HETG



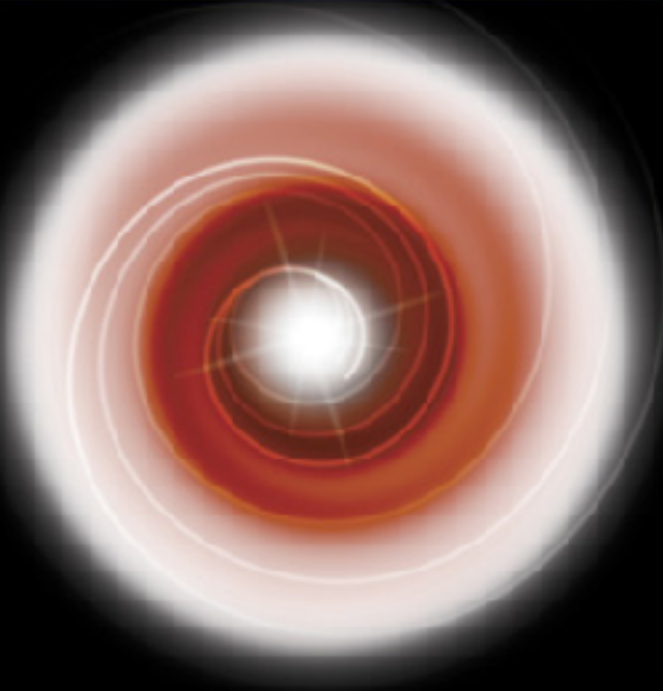
Feng, Tennant, & Zhang 2003

Black Hole Event Horizons

Black Hole X-ray Nova

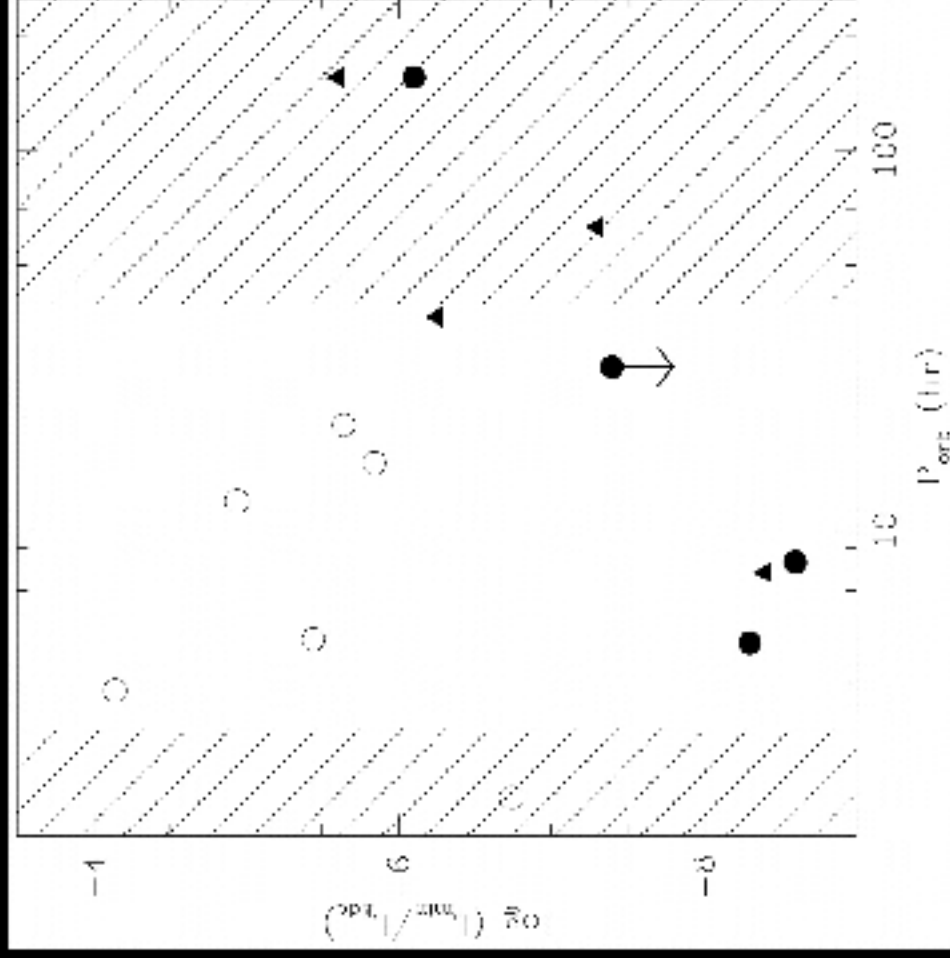
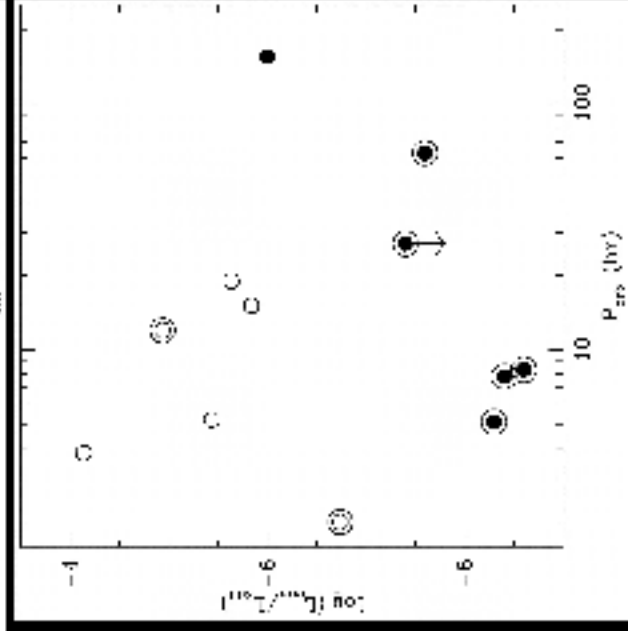
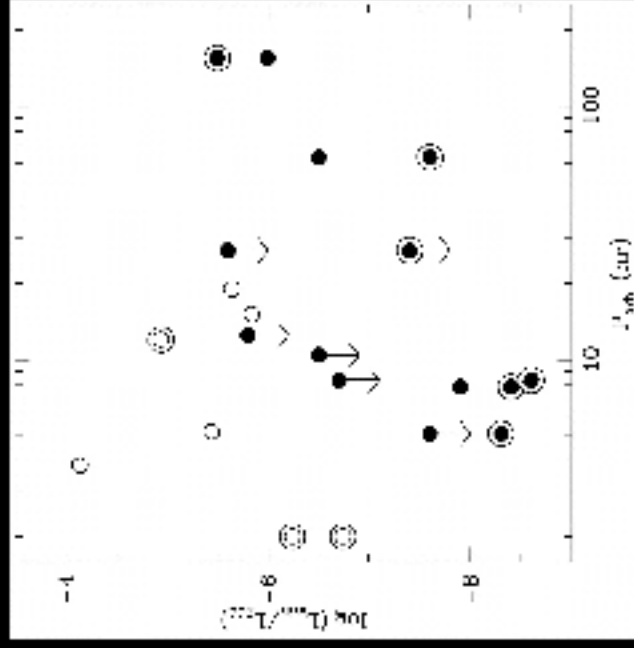


Neutron Star X-ray Nova



Garcia et al 2001

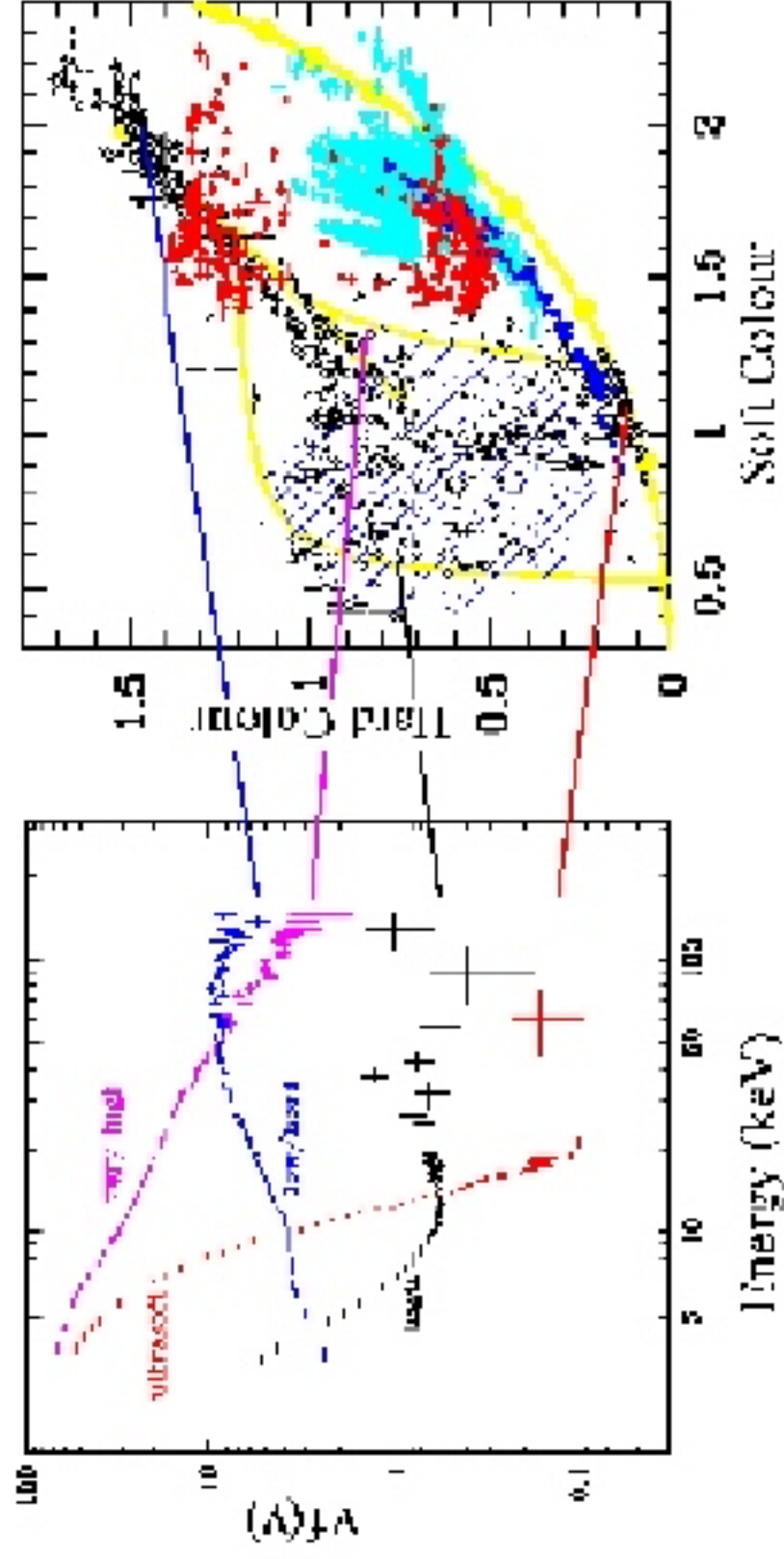
Black hole event horizon



Kong et al 2002

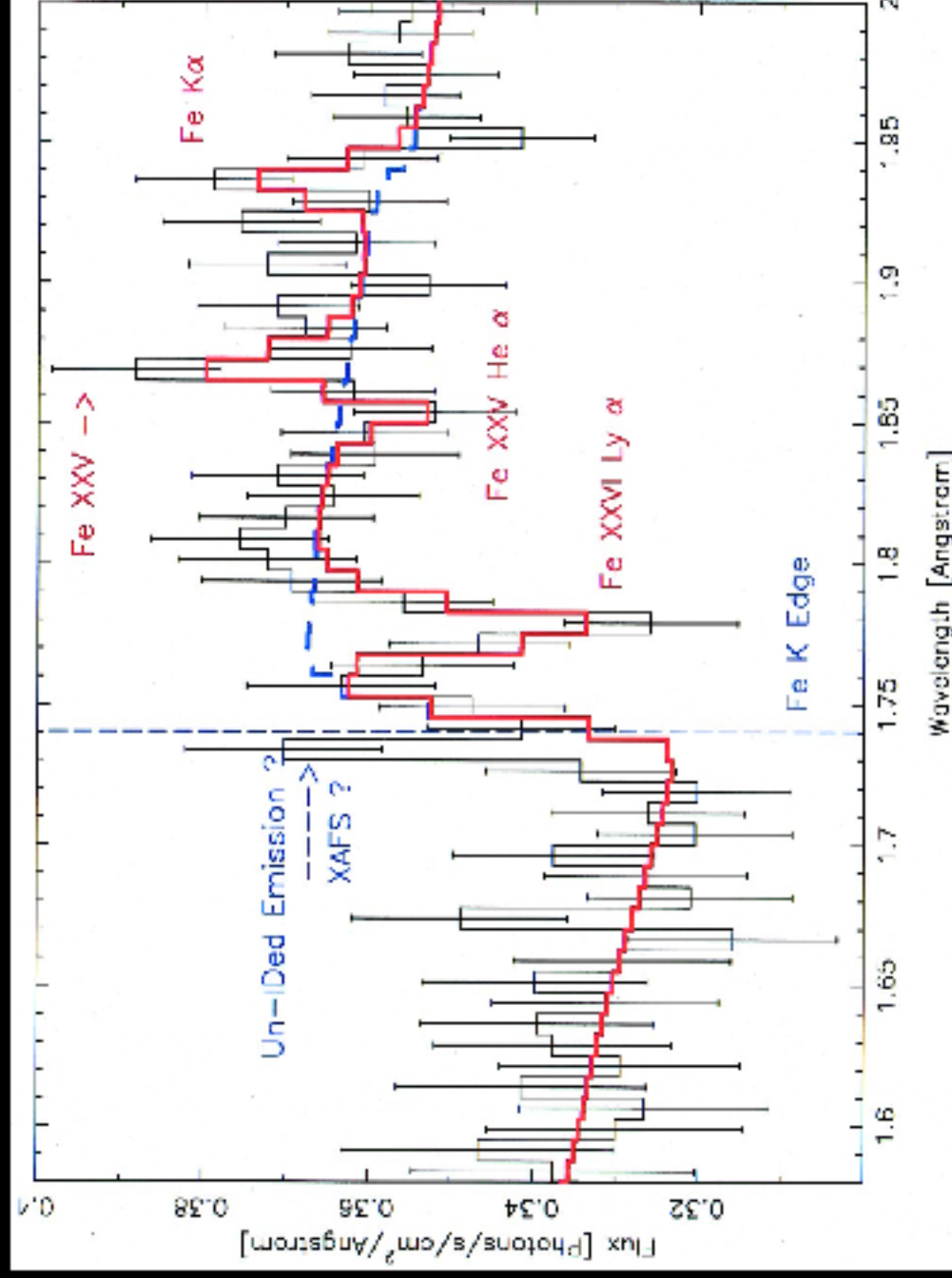
Garcia et al 2001

Black Hole Event Horizon



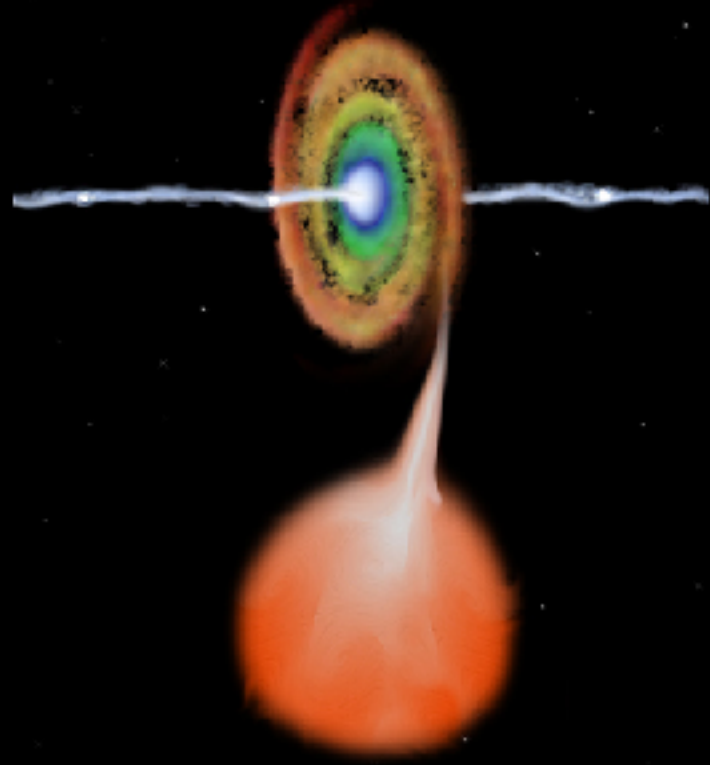
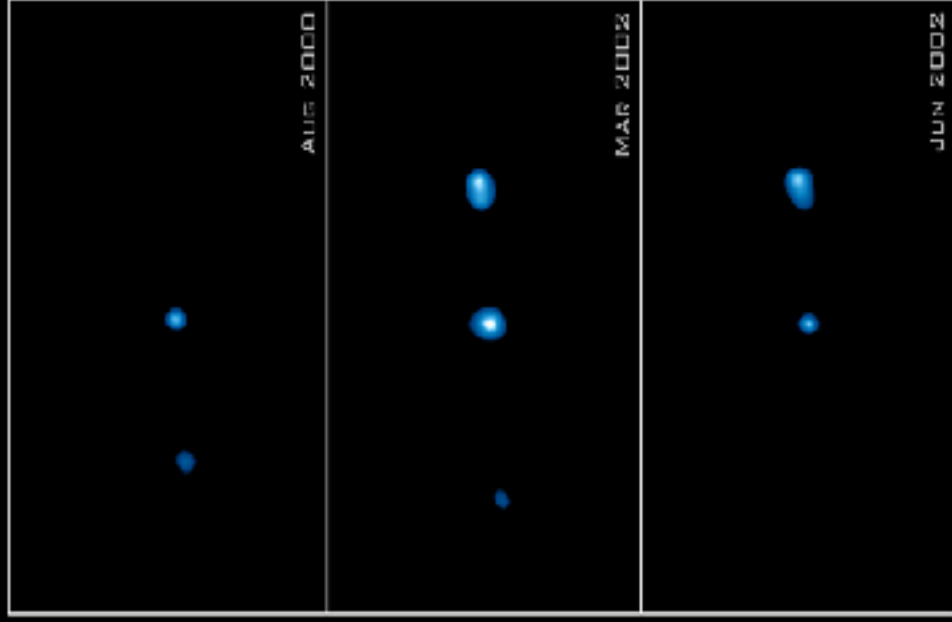
Done & Gierlinski 2004

GRS1915+105 with HETG



Lee et al 2001

Jets: XTE J1550-564



X-RAY BINARY SCHEMATIC

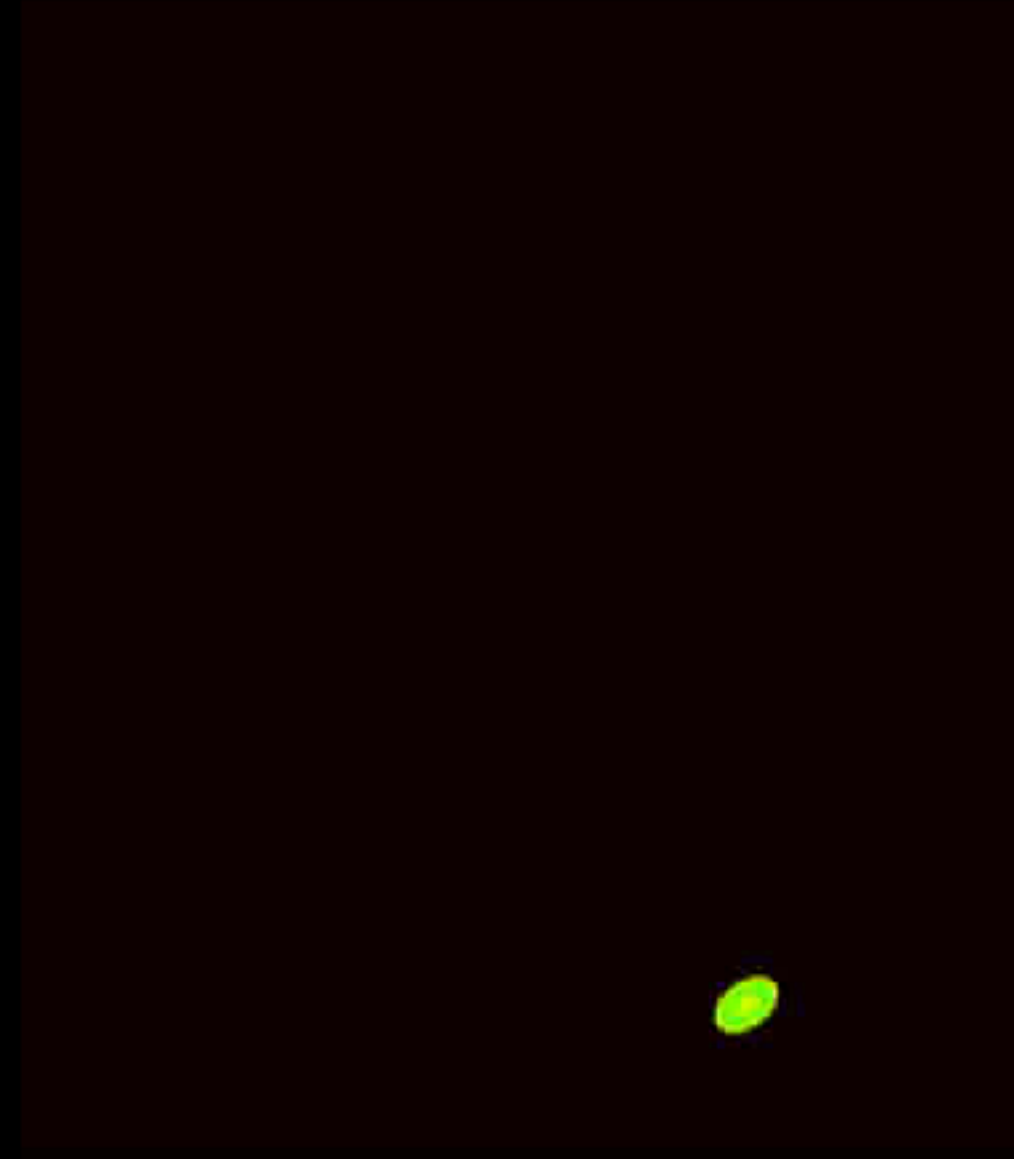
ACIS/HETG

Corbel et al 2002

XTE J1550-564 Time Lapse

NASA/CXC

Jet Model XTE J1550-564

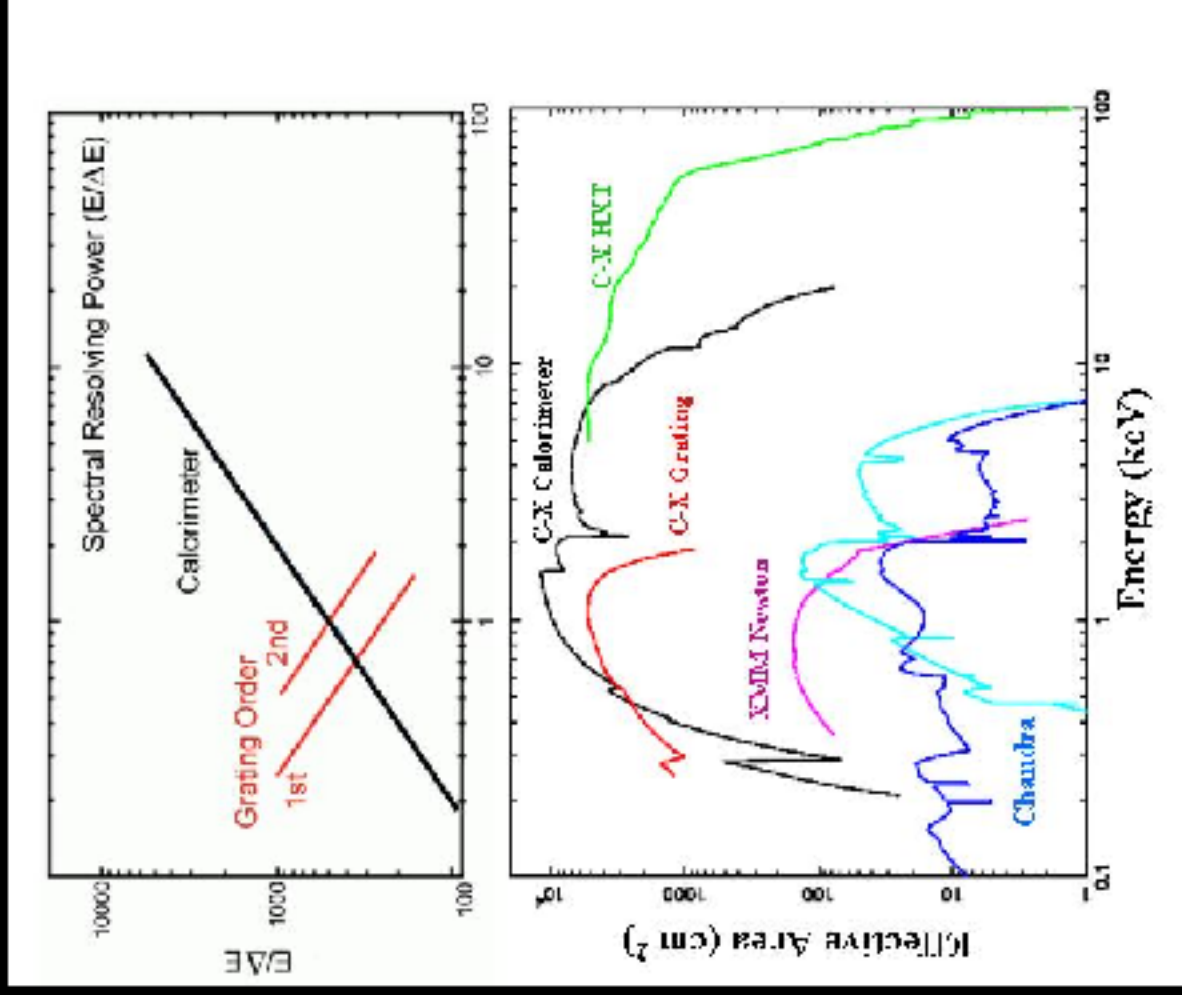


Tregillis, Jones, and Ryu 2002

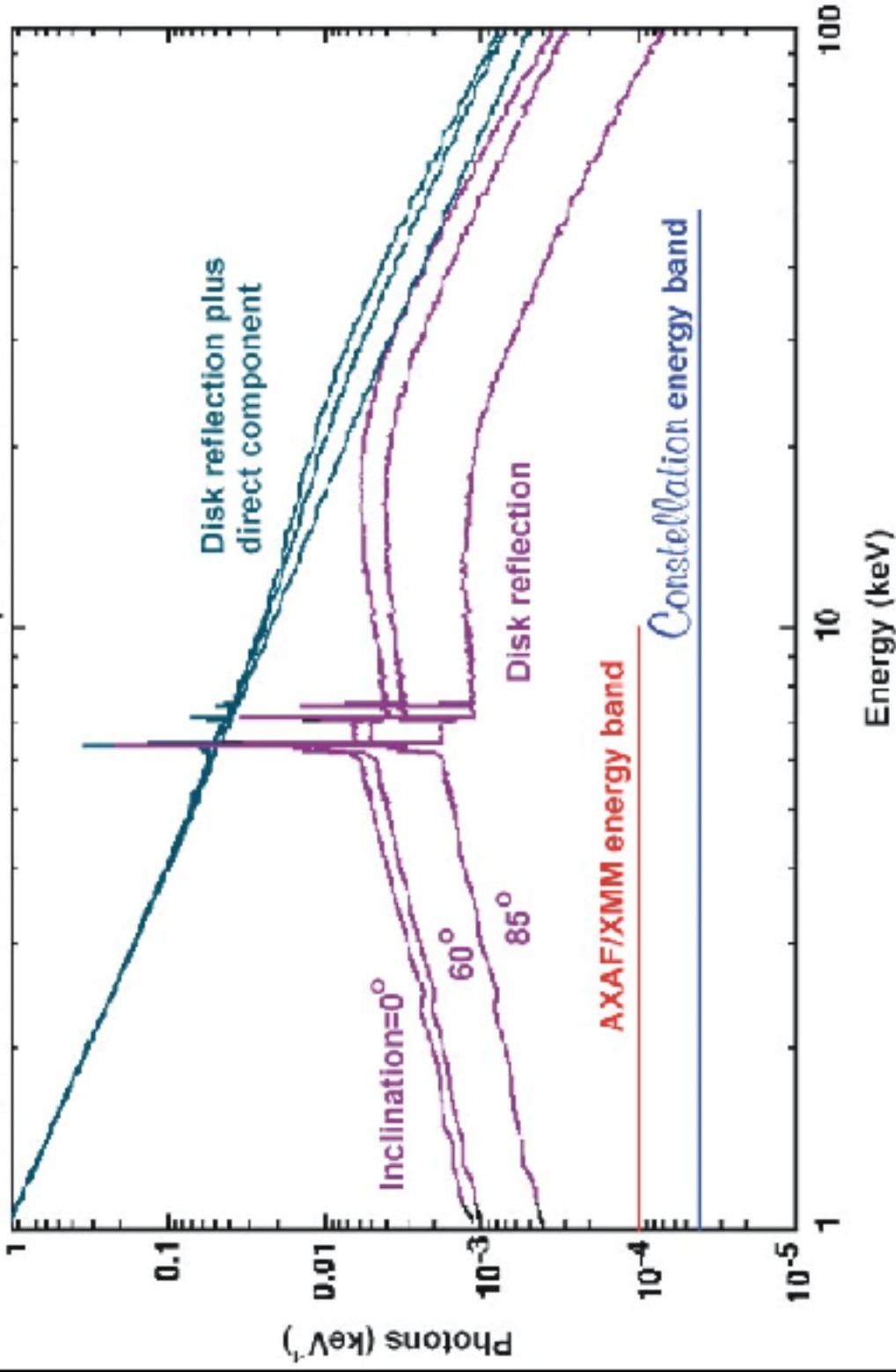
Beyond Chandra and XMM

- Astro-E2
- Constellation-X
- X-ray Polarimetry
- X-ray Interferometry

Effective area and resolution

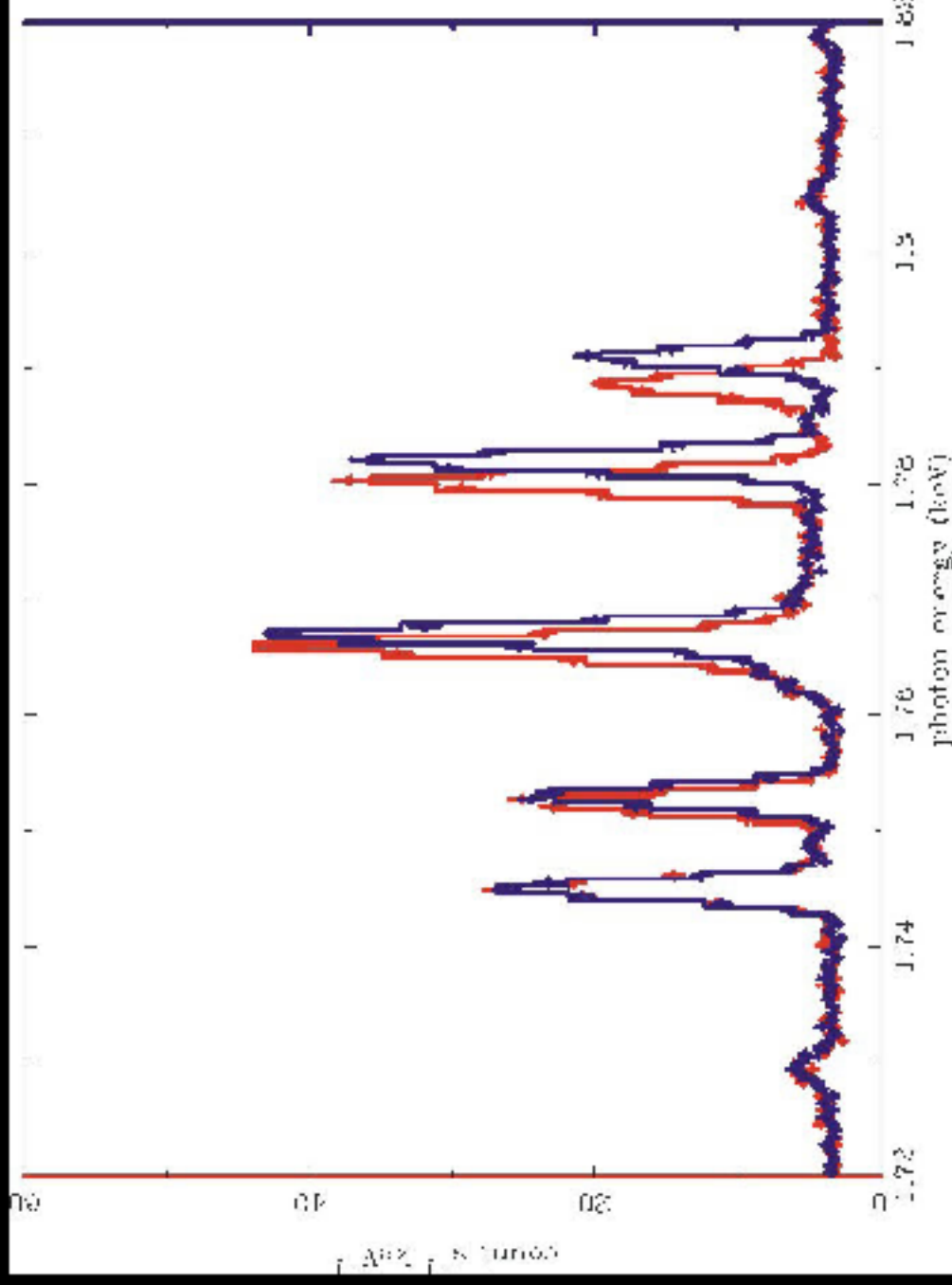


The Contribution of the Reflection Spectrum from an Accretion Disk



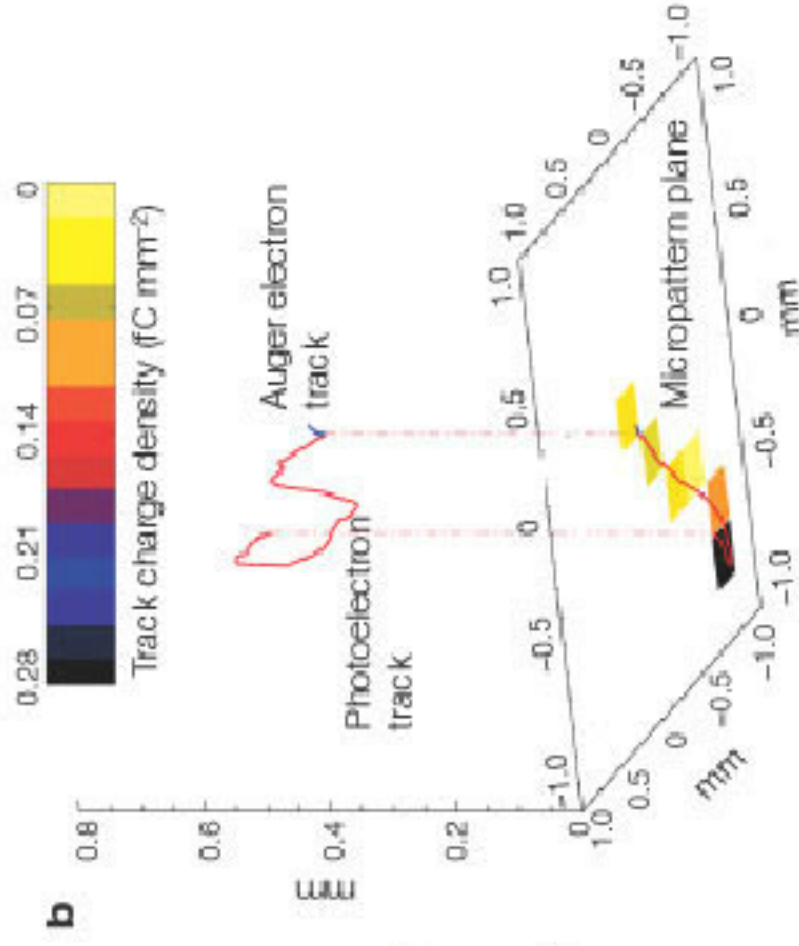
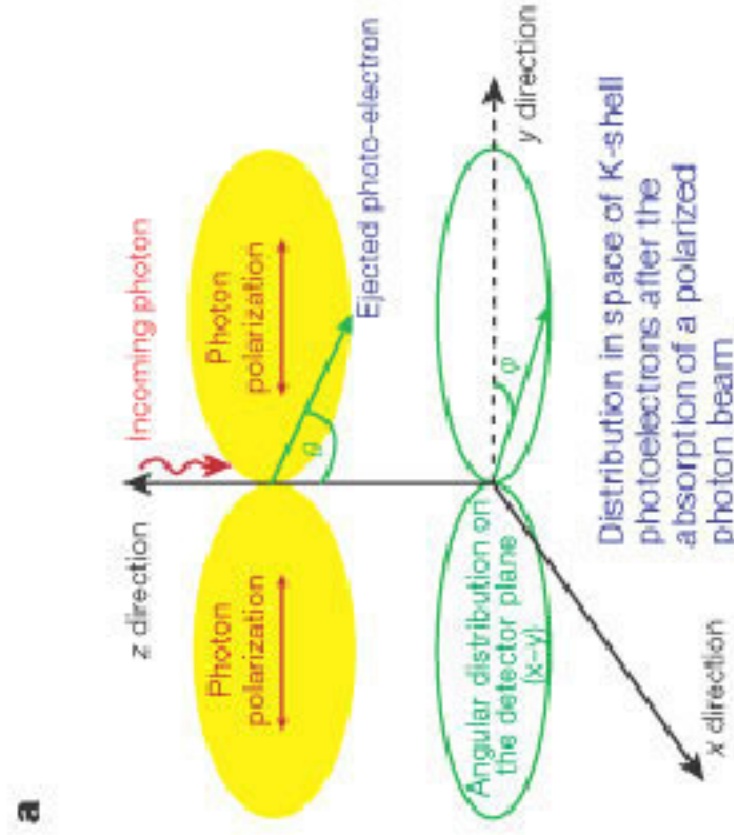
constellation.gsfc.nasa.gov/science/example/bh.html

Vela X-1 Si K with Con X



constellation.gsfc.nasa.gov/science/example_science/endpoints.html

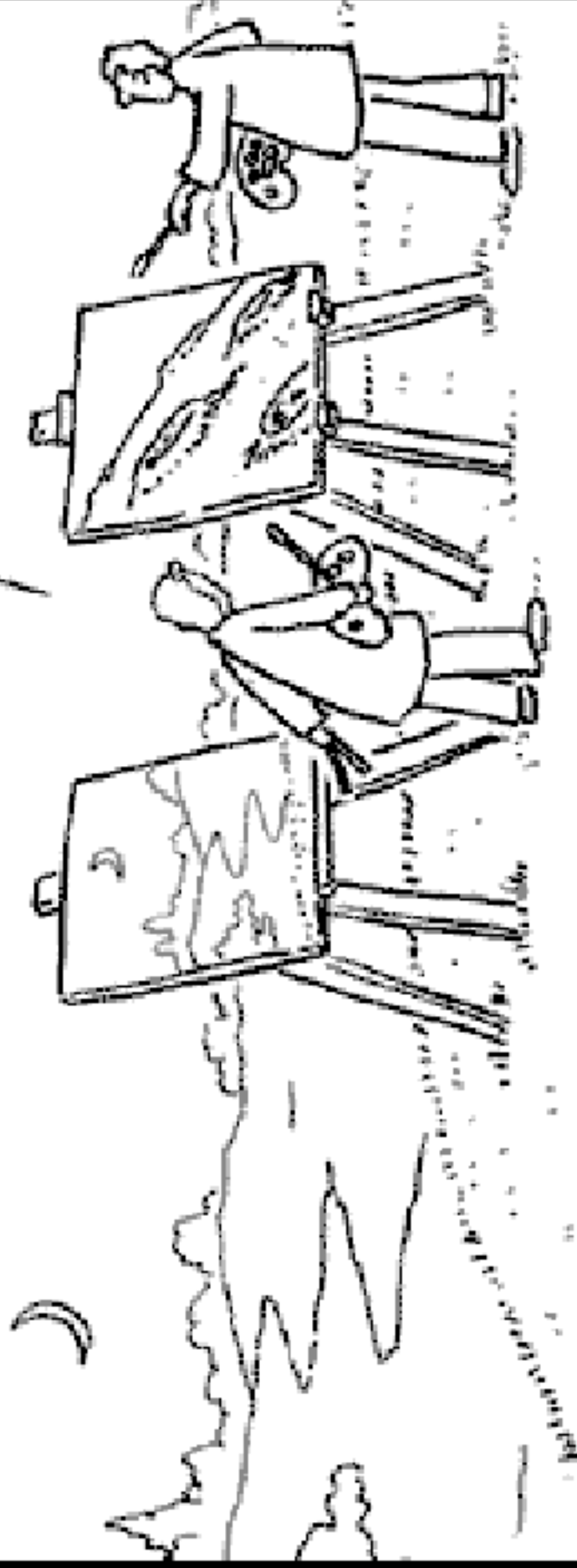
An Efficient X-ray Polarimeter



Costa et al 2001

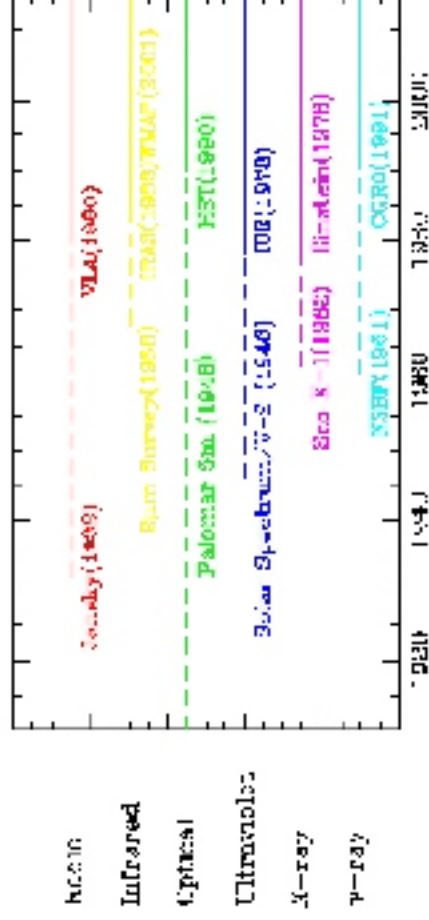
Going out of Focus.

YOU'VE GOT
VERY GOOD EYESIGHT.

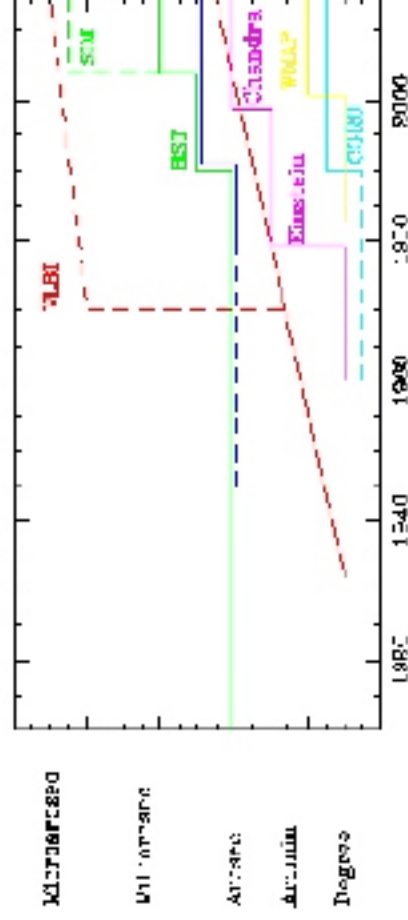


Angular Resolution

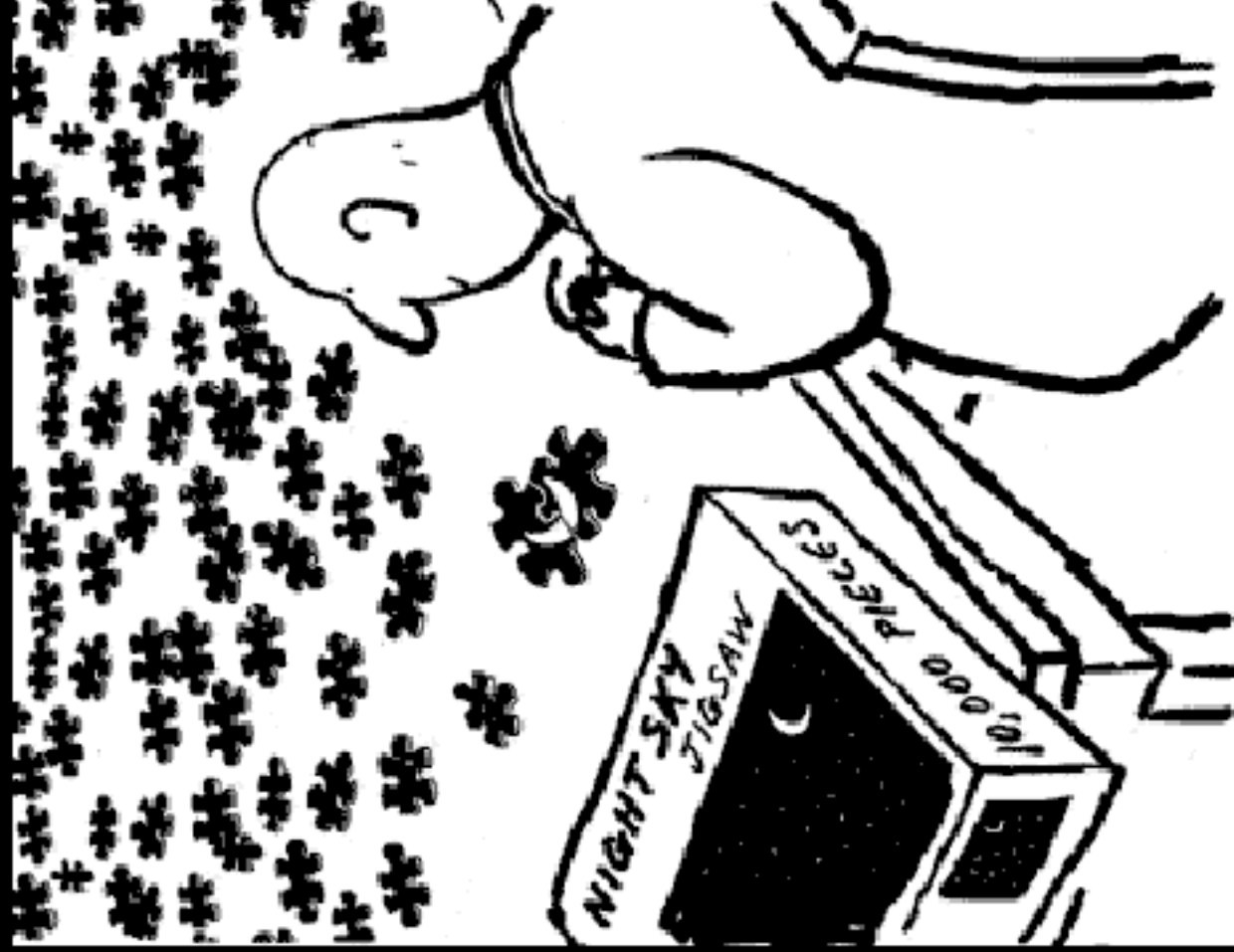
Spectrum Coverage: Getting the Whole Picture



Angular Resolution Seeing the Details

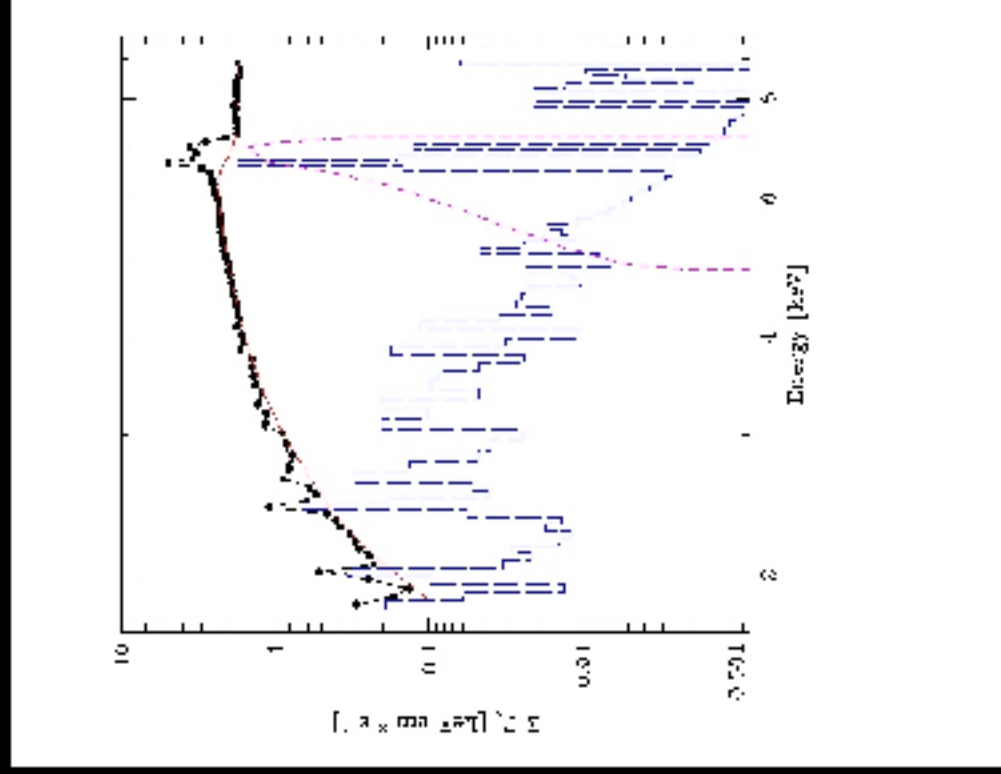


Still a ways to go!



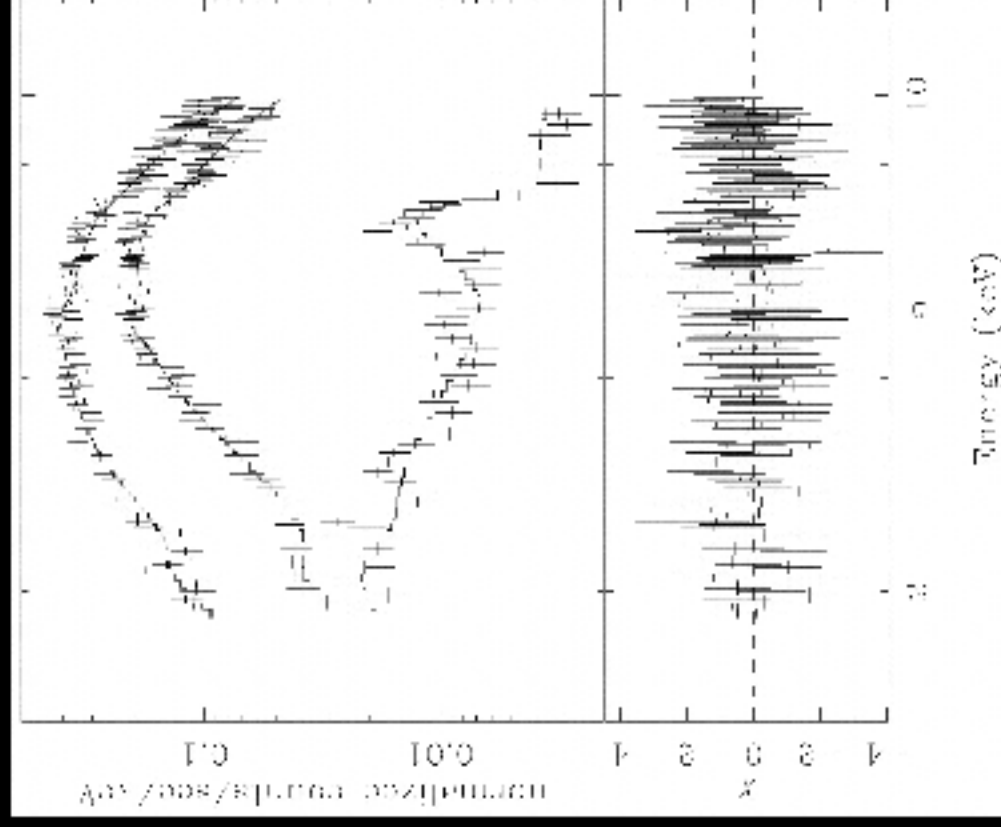
Chris Madden cartoons

Cyg X-3 with BeppoSAX



Szostek & Zdziarski 2004

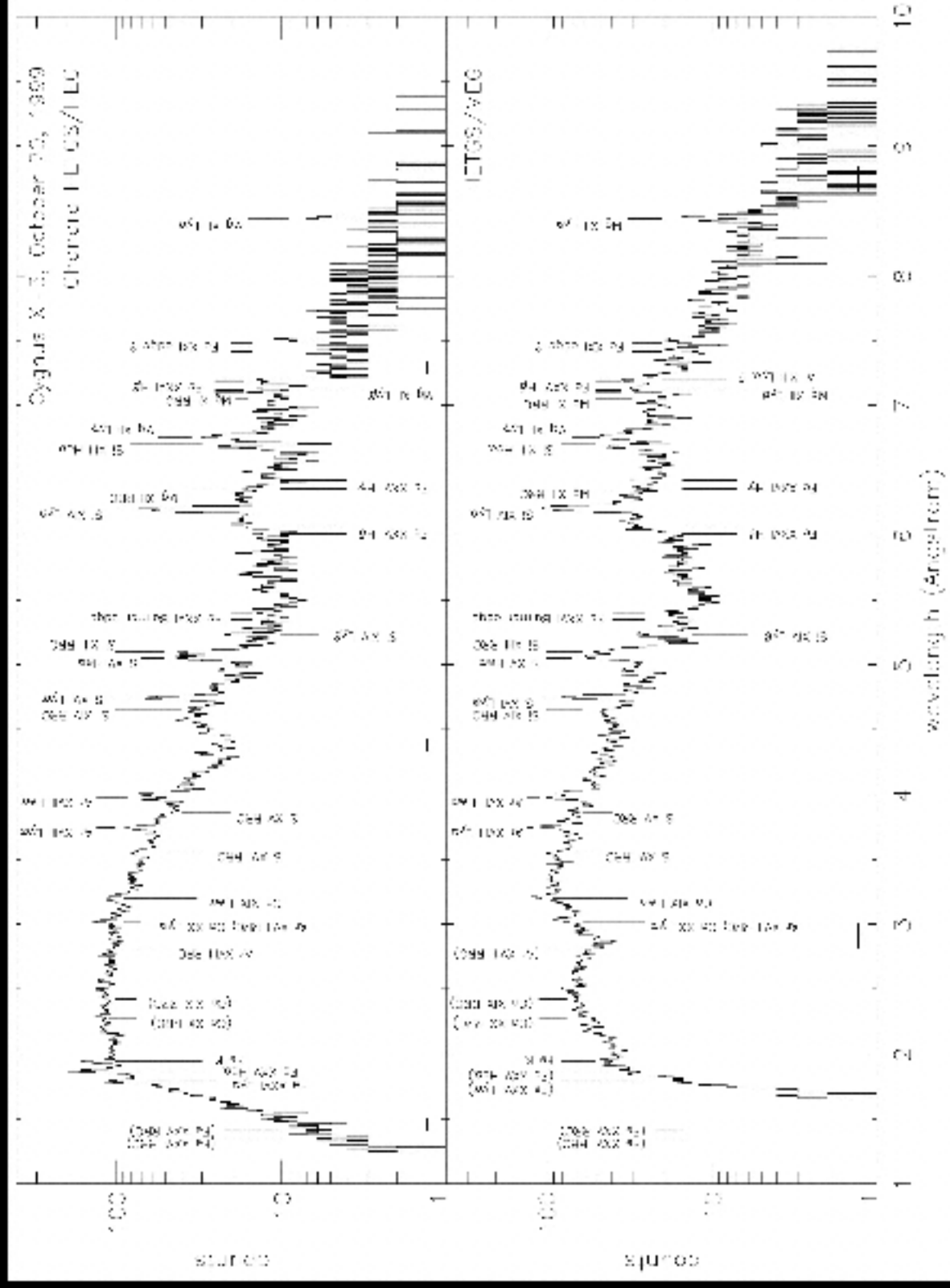
X-ray Pulsar 4U1538-52



BeppoSAX

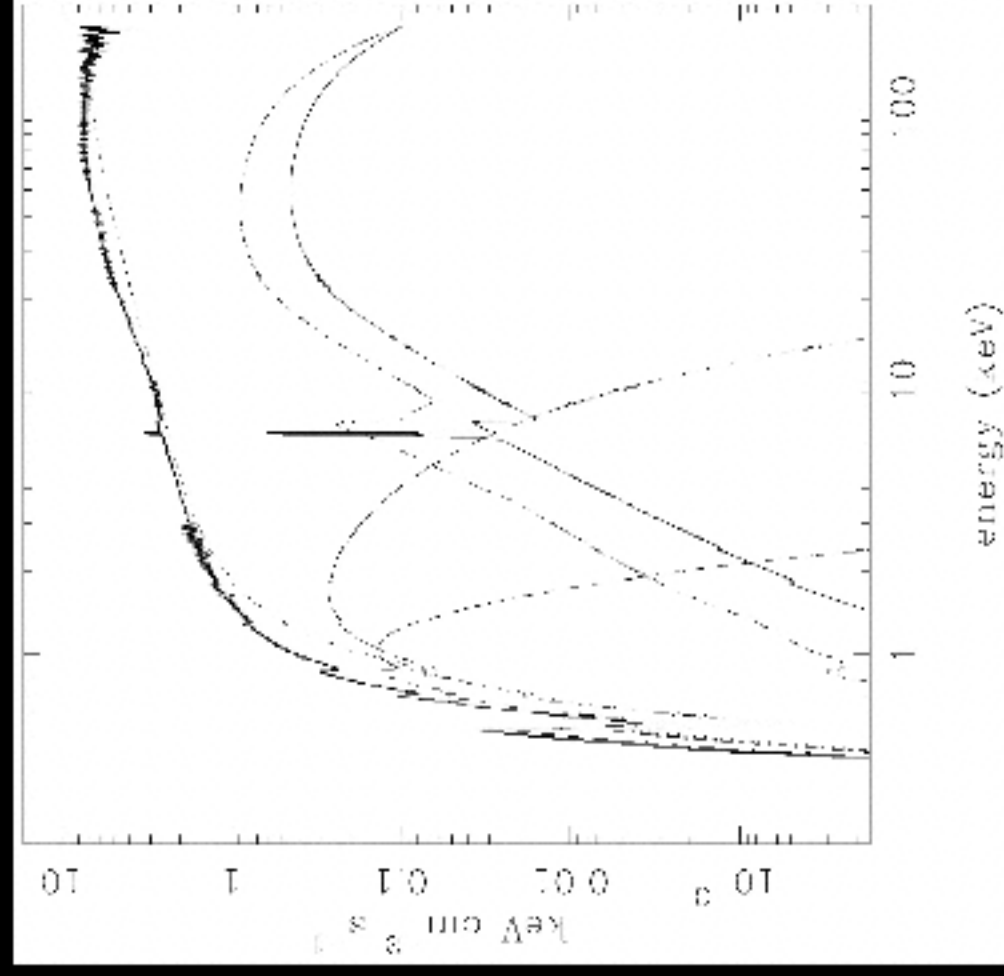
Robba et al 2001

Cyg X-3 with Chandra HETG



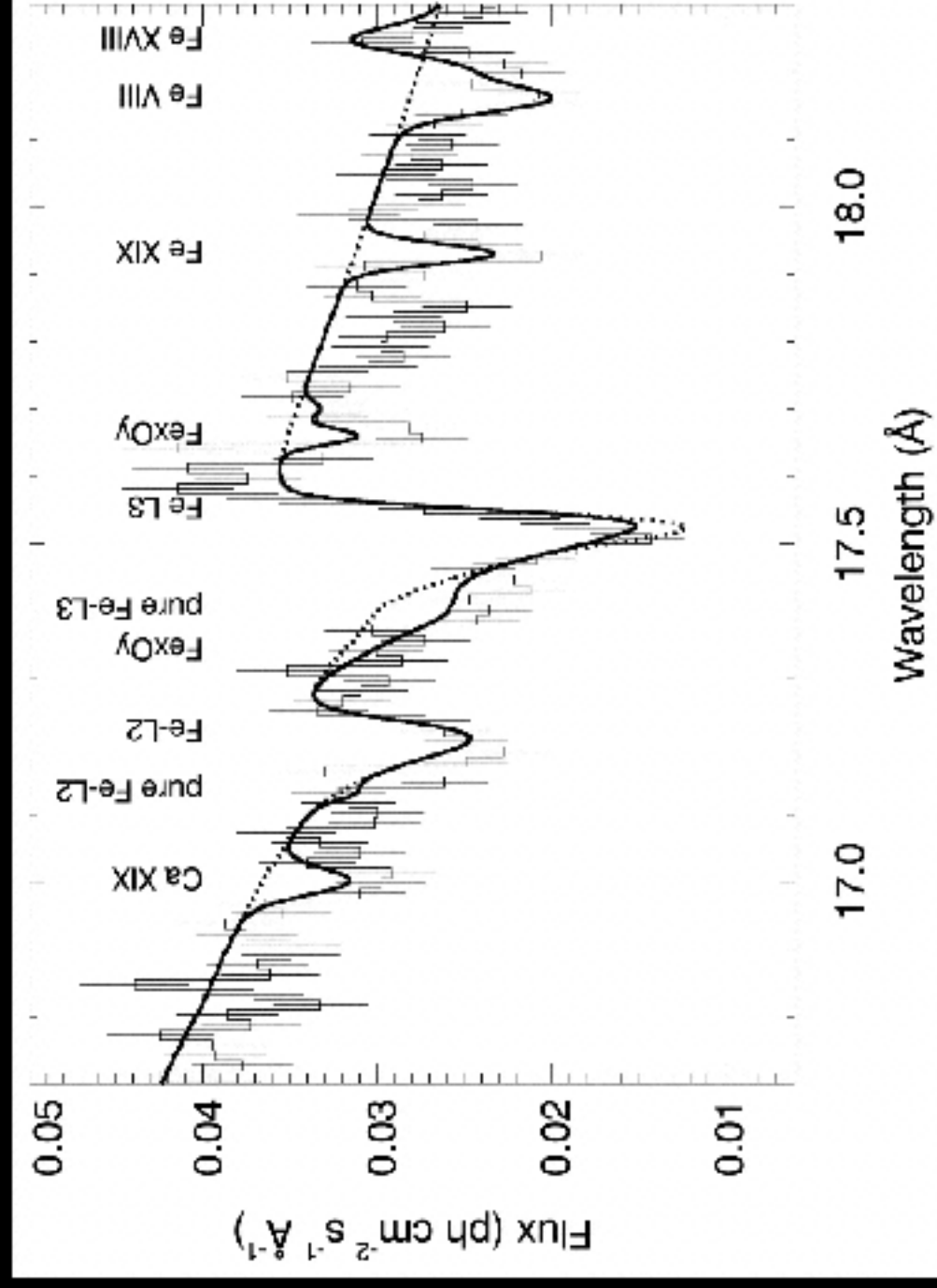
Paerels et al 2000

Cyg X-1 with BeppoSAX

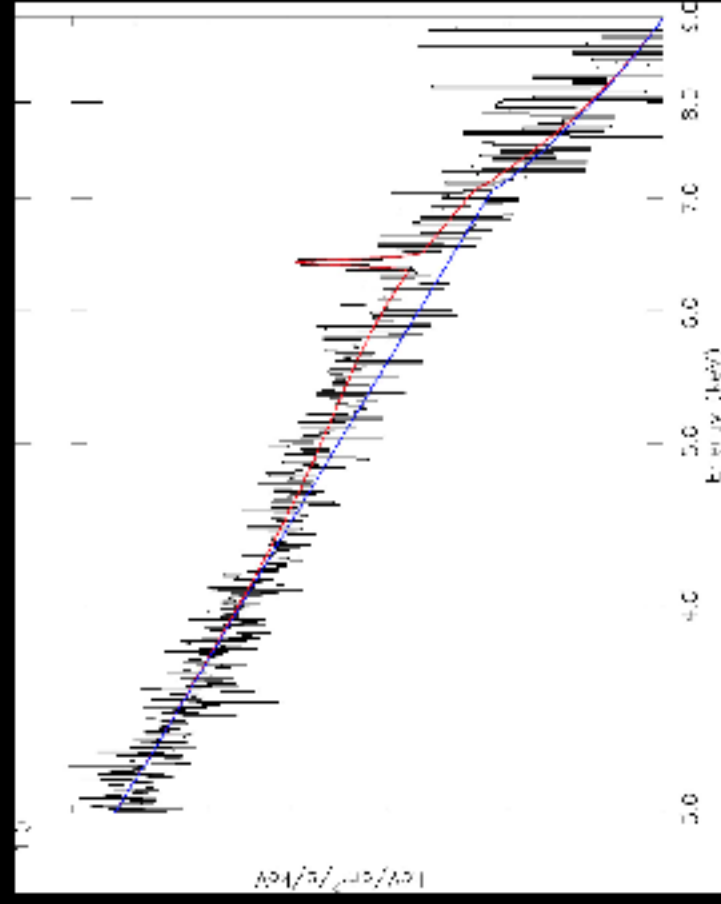
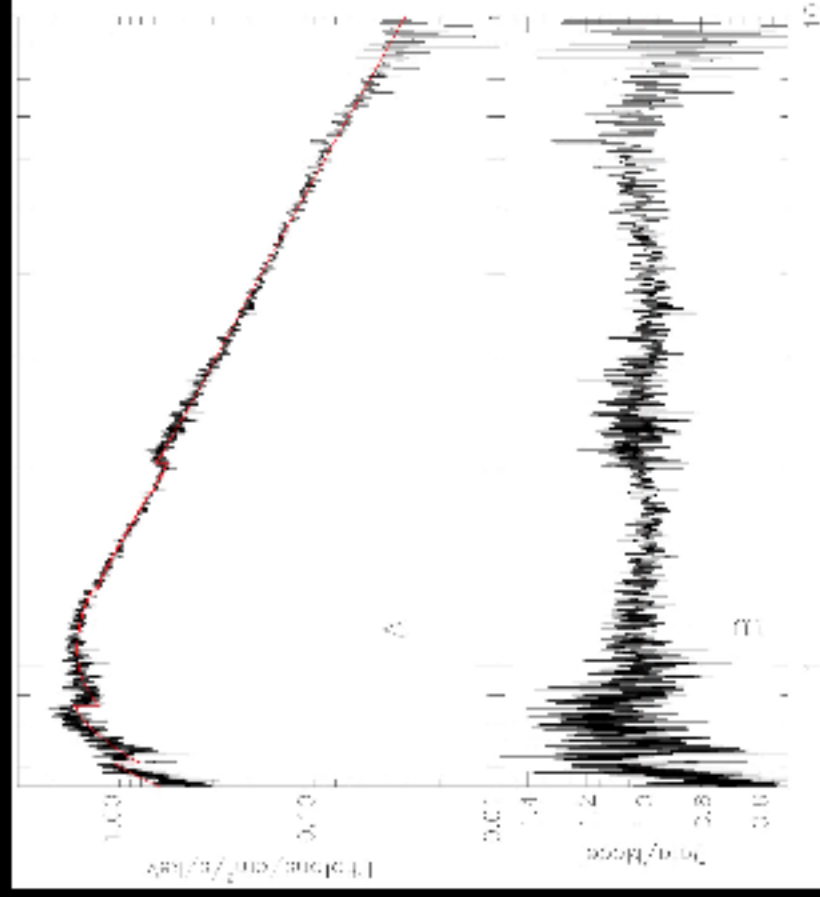


Salvo et al 2000

Cyg X-1 with ACIS/HETG



Cyg X-1 with HETG in CC mode



Miller et al 2002